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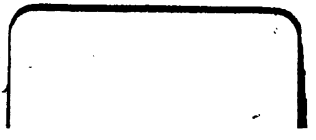
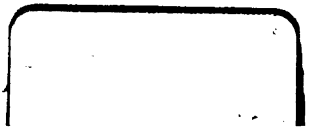
THE PRACTICAL GUIDE TO THE USE OF MARINE STEAM MACHINERY

DONALDSON.





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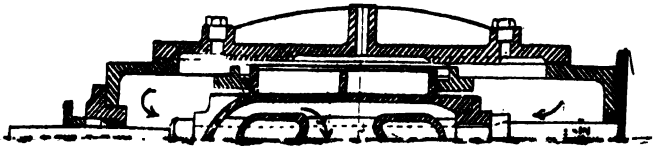

THE PRACTICAL GUIDE

TO THE USE OF

MARINE STEAM MACHINERY,

AND

INTERNAL MANAGEMENT

OF

SMALL STEAMERS,

STEAM YACHTS & STEAM LAUNCHES.

By JAMES DONALDSON, Engineer,

Author of "Drawing and Rough Sketching for Marine Engineers." "The Engineers' Annual," Etc.

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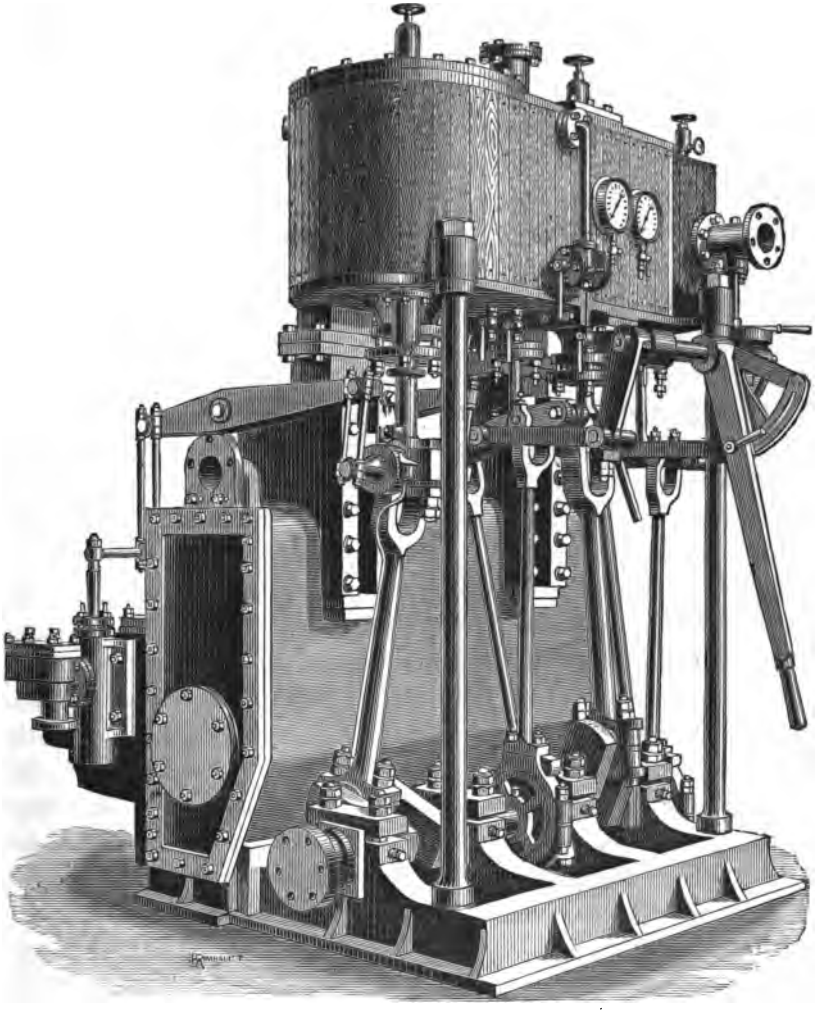


INVERTED DIRECT ACTING COMPOUND SCREW ENGINE OF 25 NOM. H.P.

PREFACE.

THE production, of "The Practical Guide to the Use of Steam Machinery," is an attempt to provide information, specially in regard to the common place usages and method of handling the Engines and Boilers of Steam Yachts, Launches, and small craft in general. Intended for the use of the Non-professional Engineer Yachtsman who may be on occasion thrown upon his own resources; or who may wish to acquire a sufficient knowledge of the subject to enable him to drive the machinery of his yacht or launch with safety, without studying the more abstruse or deeper subjects of Marine Engineering, necessary to the professional engineer. Also with hints and comments useful to those who may be concerned in the purchase, maintenance, and responsibility, of such machinery; and young engineers who may be about to proceed to sea for the first time.

The substance of the Work is chiefly the result of experience, and conclusions drawn from facts, obtained from many sources. Great assistance has been given by several practical engineers afloat; thanks have more particularly to be given to Mr. W. M. CARTE of H.M.S. *Tyne*, and Mr. W. LANG, of the Merchant Service, who gave their ready co-operation in collecting data for the Work; also to several Engineering and Building Firms who have placed the results of their experience at our disposal.

J. DONALDSON,

Birkenhead.

THE PRACTICAL GUIDE

TO THE USE OF

MARINE STEAM MACHINERY.

Introductory.—Steam although a means of obtaining ease, comfort, and speed, totally unknown to the ordinary sailor; enabling the engineer yachtsman to ignore winds, currents and tides, a useful and valuable servant; yet the responsibility of its control, its subjection to his will, is not taken altogether with impunity. The greatest care and close attention is imperatively demanded from those entrusted with its generation and use —no trifling of any description or the slightest negligence can ever be allowed. It is ever ready to turn upon the hand that feeds it, should the eye be turned away or the attention withdrawn.

It cannot be too strongly impressed upon the minds of those into whose hands the charge of steam machinery may fall, that nearly all accidents happen through neglect, and that everything that a good engineer does with his machinery while under steam, is done with a view to what may happen.

Class of Engines.—The greatest number of steam vessels afloat of all kinds, are fitted with machinery of one of several types, belonging to one general class—that is the Inverted Cylinder Direct Acting Engine and the Cylindrical Return Tube Boiler.

The engines of steamships and yachts above a certain size are commonly one of three types—High Pressure Engines, with one or two cylinders, Condensing Engines, with two cylinders, or Compound Engines, with two cylinders, also Compound Non-Condensing Engines, with two cylinders, and with the Circular Return Tube Boiler.

Launch Engines are invariably high pressure engines, with one or two cylinders, supplied with steam by the locomotive or vertical boiler.

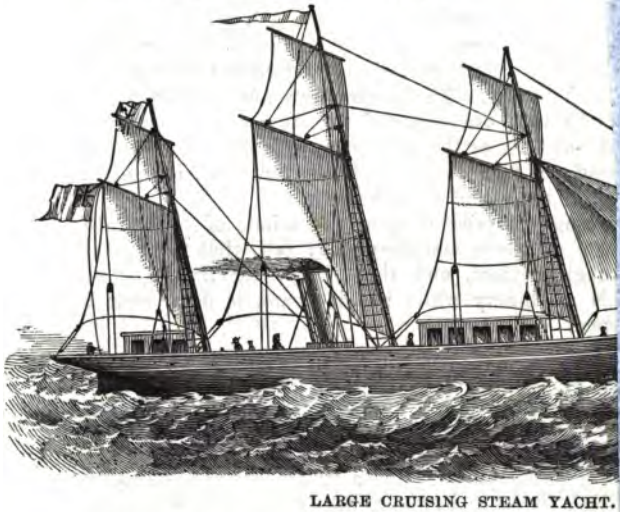
Throughout the following pages it is these types that are referred to, the remarks and instructions being common to all, unless where otherwise mentioned.

There are several other kinds of engines of various descriptions, many of them belonging to the three cylinder class, with steam on one side of piston only. These are only used for very small boats, and require special mention by themselves, each individual engine being handled in a different way, though generally it is simply by opening or shutting off steam by means of a valve or cock.

General Instructions.—We here proceed to
and draw attention to some of the most partic
the economy, care, and management of the mach
steam yacht.

Endeavour to understand the action uses and
the engines ; all cocks and valves, where they
communicate with.

Be familiar with the precise state of the boil
corrosion, pitting, wear and tear, signs of decay,
and probable life. Search out all thin places in t
the deterioration increases while under the cont
owner. Understand thoroughly the action of the
certain they are correctly weighted.



LARGE CRUISING STEAM YACHT.

Be clear upon what to do when starting and s
and the probable mode of action to take in th
emergencies, or breakdown. Note the quantity of
steam at the working pressure for a given time, and
of coal carried in the bunkers, to provide against a
short in out of the way places where coal cannot be

The crew of a boat running short of fuel may at t
in a very awkward predicament. Even at landing pl
times have to be brought from a distance, which is
an annoyance, besides entailing a loss of time.

Preparations.—In the case of a steam vessel or
laid up for some time. It is advisable for the e

charge of the machinery, to have a day or two to get things cleaned and examined; to see all the bearings overhauled and put in working order, all packing and stuffing boxes re-packed; to see that the safety valves, stop valves, all the cocks and communications with the boiler and with the skin of the vessel are in order, and not set fast, and that they can be easily opened and shut without unnecessary strain being put upon the spindles—all cocks and valves if tight when cold, are certain to set fast when heated. The plugs of cocks, especially the plugs of blow off cocks, should be taken out, cleaned, and oiled, whenever opportunity permits, such as when the vessel is beached or in the graving dock.

It should also be seen if there are any bolt heads or studs eaten away by corrosion at the joints where bolted to the boiler; this may be specially looked for at the branch pipe of the bottom blow off, where jointed to the boiler, at the discharge valves, Kingston valves, and sea suctions, where bolted to the plating of the vessel; also gland studs of cocks subject to the application of heat or steam, or any part where iron and copper or brass are in contact and water present, and specially where the metal is liable to fluctuations of temperature.

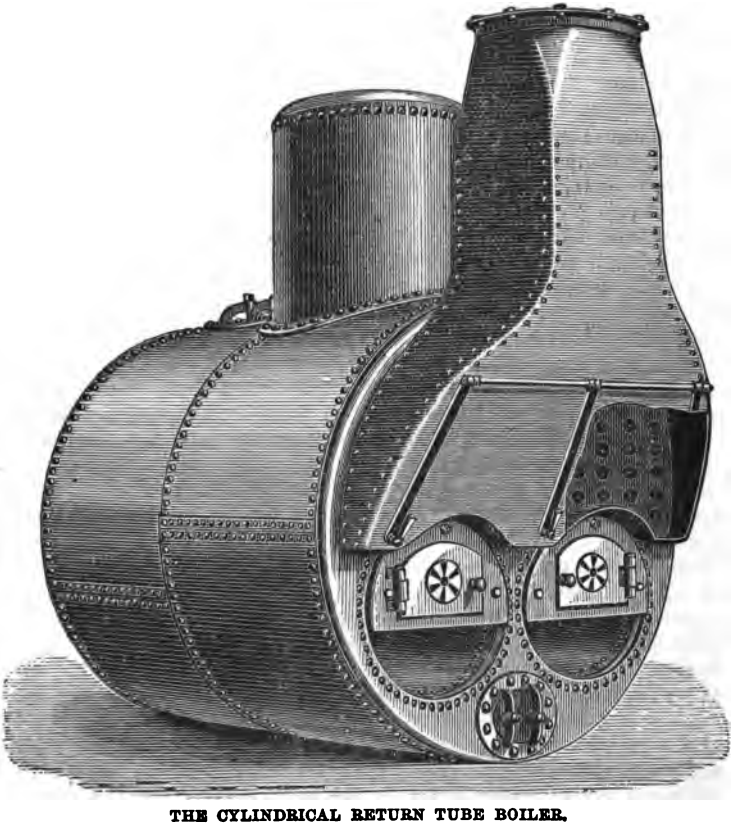
"Voltaic electricity is produced whenever two dissimilar metals are in the same liquid touching each other, the most oxidisable is acted upon very rapidly, the least is not acted upon at all."

Filling the Boiler.—The engineer or attendant should satisfy himself before attempting to get up steam that there is enough water over all internal parts of the boiler exposed to heat. The force of this will be apparent when it is remembered that more accidents occur through insufficient water than all other causes put together. Prior to admitting water he should satisfy himself as to the positions of the highest part of the furnace crown, in relation to the water gauge; this level should be found, and a mark made upon the lower gauge cock, or upon the front of the boiler, to indicate the point; by assuring himself of this beforehand, confidence and a sense of security is gained, by the knowledge of always being able to tell precisely what water there is over the crown plates. If the working level of the boiler is under the draught line or level of the sea, the boiler may be run up through the bottom blow off cock, if otherwise, it will have to be pumped up by the donkey pump, and in small craft where there is no donkey, by the hand-pump, or, as is sometimes the case with small launches, with a hose pipe, or bucket.

If the top manhole is left open when running up the boiler, the level of the water can be watched when it rises to the furnace crown, and the position on the front plates noted on the inside by the laps or rivets and transferred to the outside: or if the bottom cock of the water guage be left open, the appearance of the exit of water can be watched, and the depth measured inside over the furnace crown and tubes, always supposing the vessel to be on an even keel, or in her usual sailing trim or draught of water fore and aft, otherwise this will have to be allowed for.

It is usual when fixing the water guage upon the boiler by the

engineers or builders, to place it so that the centre of the bottom cock is an inch over the level of the fire box crown, or the highest part exposed to flame, and afterwards to work with eight inches of water above the centre of the cock; however, the latter depends materially upon the size and construction of the boiler, and the best working level can only be known by experience with the particular boiler in charge; still, when the level of the crown is known, and marked plainly and indelibly with a chisel cut, a line of white paint, or, as is sometimes done, with a brass plate and pointer, it can always be readily known what water there is in



THE CYLINDRICAL RETURN TUBE BOILER.

the boiler, and what chance there is of the tubes becoming bare when the vessel is pitching and rolling at sea. The working level should also be marked, making allowance for any difference of trim likely to occur from full and empty bunkers of coal, and other load or cargo likely to alter the draught of the yacht.

In no case should the fires be lighted until the boiler is full of water, otherwise the boiler may be seriously injured by the unequal expansion of the plates of which it is composed. Although in cases of expediency it is sometimes done to raise steam quickly, the practice is by no means to be commended. Make sure that the water is up to the usual level, all the better if higher, as when the water begins to heat, the cooler water at the bottom can be drawn off by the blow-off cock, which will assist to circulate and equalize the temperature of the water. By leaving the manhole or openings above the water open, also assists to keep the surface cool and equalize the water.

See that all cocks under water are closed.

Lighting the Fires.—When the boiler is filled, the lighting of the fires may be proceeded with.

The fire grate being laid with a plentiful supply of dry wood, is kindled in any way most convenient.

The stokers should not be allowed to collect old or used greasy cotton waste, and store it away for the purpose of lighting fires. No doubt it is very handy to light up with, but it is very liable to ignite with heat, and sometimes, it is said, by spontaneous combustion; however that may be, it is certainly a dangerous article to have stowed away amongst coals in the bunkers or other part of the stokehole.

In the event of its catching fire, the smoke is so dense and the flames so overpowering that serious risk may be run before the seat of the conflagration can be got at. The practice should be discouraged: many accidents of fire have had their origin in this—even Atlantic steamers have been placed in jeopardy, and all efforts of the crew set at defiance with cases of asphyxia.

When the wood in the furnace is sufficiently ablaze, and the ashes settle down into a glow, nuts of coal are put on gradually until a good fire is built up.

The fires should not be forced, but be allowed to take their own natural course until the boiler is thoroughly heated. Light the fires as long before steam is required as conveniently practicable; forcing steam, if raised from cold water, will ruin the boiler.

All advantage should, at the same time, be taken of the natural draft caused by the difference between the heated air in the funnel and the atmosphere, augmenting it as much as possible by causing all the air required for combustion to pass through the fuel on the fire bars, and not by the fire door or smoke-box doors.

The blast, or small steam pipe from the boiler leading into the funnel, is much used in small craft to create a draft, the end of the pipe, or nozzle, being contracted to create force; but, of necessity, this cannot be used until a pressure of steam is raised in the boiler.

Circulation, Expansion of Plates, Etc.—If the circulation of the water can be assisted by the donkey feed pump so much the better, but

few boilers are so fitted, that is to pump from the bottom or cooler part of the boiler and discharge into the upper part near the surface, or by the use of the Hydrokineter—this can only be used when a donkey or auxiliary boiler is carried in the vessel (*see* page 34).

When the boiler begins to get warm, open the safety valves to emit hot air; also when steam begins to show, open the stop valve and communication to the engine, so that the cylinders may be gradually warmed-up also. Any sudden change of temperature always has an effect upon the metal, especially the working parts of the engine; the pistons will be tight, and the valves have excessive friction, and be liable to stick, owing to the more rapid expansion of the thinner, generally the working parts, over that of the more solid stationary parts, such as the dense mass of metal in the cylinders, framing bed-plate, etc.

Try the water gauge frequently whilst raising steam. It is only by actually opening the gauge cocks that any one can be positive as to what water is in the boiler.

Examine all the oil cups and worsteds, and lubricate carefully all the bearings.

The piston rod and valve spindle packing should not be allowed to get hard as it will mark the rods, and should be examined and renewed if required.

Hot piston rods are generally caused by being too tightly packed, therefore the glands should not be screwed up too tight.

Steam Blowing-off at the Safety Valve.—It is considered a gross want of judgement or incapacity amongst engineers to see steam blowing-off in quantity at the safety valve, this should be studiously avoided, as it is not only a waste of steam, consequently a waste of fuel, but the noise is very disagreeable, and to nervous persons who may be passengers for the nonce, is very liable to cause apprehension.

With many small craft when the steam rises to the blowing-off point the valve rises suddenly with a flop, throws out of the escape pipe an immense amount of condensed water and dirt. If there is not a drain cock on the bottom of the waste steam pipe or valve chest, it would be well to ease the valves before starting, and endeavour to throw the water and dirt out to the lee side of the boat, while on the alert for it, so that it will not take one by surprise when it is unexpected, otherwise a mess of this kind will often cause a deal of annoyance.

Precautions to be adopted before Starting the Engines.—Before starting the engines, see that the injection valve and all discharge valves are open, also the feed suction and boiler check valve.

A starting valve is placed in compound engines between the high-pressure casing and the exhaust, so as to pass steam direct to the low-pressure cylinder; it is generally used when starting to assist the low-pressure engine previous to a good vacuum being formed. Sometimes the steam stop valve is shut off for a few minutes just before starting,

and the injection valves opened, so that the cold water getting to and cooling the condenser will assist the vacuum in starting, which is of great advantage with compound engines. In case the high-pressure engine of a pair of compounds was to break down, the starting valves can also be utilized in working the low-pressure engine singly by passing steam direct to the low-pressure valve.

When starting or reversing the engines the expansion valve should be thrown out of gear, otherwise the ports may be entirely closed. In small fast running engines, expansion valves are not usually fitted, and, of course, to them this does not apply.

Before starting, if in port and moored at a quay or in harbour, see if the propeller is clear of ropes, etc.,

When all is ready a preliminary start may be made to ascertain that all is right. The links are thrown over by the starting gear, and the engines move as soon as steam is admitted to the cylinders by the throttle valve.

If all is satisfactory a regular start may be made whenever required.

The Action of the Engines in Starting.—When the engines are quiescent, and the links in the middle position, both of the steam ports of the high-pressure engine are closed by the valve, supposing that the crank to be nearly on the bottom stroke; but to facilitate the starting of the engines, the crank is never stopped on its dead centres if it can be avoided; therefore if the engine has stopped with its crank at some part of its stroke other than the dead centres, the valve may not be covering both ports; but as there is not sufficient motion in the valve when the links are in their middle position, even if the engine be moved by some extraneous cause, to allow of the valve travelling sufficiently far to uncover one of the ports, and allow steam to get at the alternate side of the piston, the engine remains motionless so far as steam is concerned.

The stop valve being open, the throttle valve is then opened partially at first, admitting steam to the h.p. casing and back of the valve. The blow-through valves are opened, which fills the cylinders, passages and condenser with steam, driving the air and water before it; when this has been done, and steam alone issues from the drain cocks, the blow-through valves are closed and the injection and discharge valves opened; the cold water rushing into the condenser effects the condensation of the steam which it contained, and creates a partial vacuum.

By then turning the starting wheel and throwing back the link, the slide valve is raised, until the under port opens communication between the casing and the cylinder admitting steam to the under side of the piston. The starting valve is opened, giving steam to the steam side of the low-pressure cylinder, to give additional assistance in making a revolution. The engines moving slowly and turning the centres, the motion of the eccentrics bring the valves to the reverse position, when if a little more steam be given, an accelerated motion is obtained, and

the engines are started. The circulating pump is now in action, and the steam flowing from the low-press cylinder into the condenser, there encounters a large cold surface of tubes which condenses the steam and forms a vacuum in the cylinder on the exhaust side of the piston, thereby relieving the pressure from one side of the piston, the steam pressure on the other side having less resistance to contend with, forces it in that direction.

The eccentrics being fast upon the shaft, and a rigid communication of rods intervening between them and the valves, the valves must consequently ascend and descend regularly, following the revolutions of the crank, and these revolutions are performed uniformly with the alternating ascent and descent of the pistons.

The air pump being connected indirectly with the piston rod, through the medium of the levers and crosshead links, moves simultaneously with each stroke, and with the same regularity as the valves and pistons, drawing away the water, caused by the condensation of the steam, from the condenser.

The feed pump being also attached to the air pump levers, the boilers are supplied with water in proportion to the speed of the engines, and consequently in proportion to the steam used; but this latter is not necessarily a criterion to go by, as the actual test for the feed is the height of the water in the gauge glass, and the regulation of the feed cock accordingly. Still, when a particular set of the cock is known to maintain a regular feed, it can be ascertained from the height of the glass if there is any leakage of condenser tubes, or if the supplementary feed should be used.

With many engines a difficulty is experienced when starting, unless full steam is given them; and in most cases it is the best plan to throw the links back the full distance, and regulate the admission of steam by the throttle valve, giving the engines a good supply of steam fearlessly, and when a revolution is made, to bring them up a little by throttling, at the same time assisting the high-pressed engine by opening the starting valve to the opposite side of the low-pressure piston by watching the position of the cranks, and admitting steam at the right time. When springs are not fitted to the back of the valve, care should be taken to admit steam to the receiver, or back of the low-pressure valve, before admitting it to the interior of the cylinder, otherwise the valve may be blown off its face, and cause a considerable amount of trouble and delay to get it back again into its place.

Attention required after Starting.—As soon as the engines are started all the bearings and working parts should be examined to see if they are heating, also that the pumps are acting, the condenser doing its duty, and the boiler receiving feed. The engines should not be worked by wire-drawing the steam through the throttle valve more than is necessary, but by expanding the steam by cutting off as early as possible by the links.

When fairly under way, if the engines are in good condition, little trouble will be given; but it is still necessary for the engineer to keep an eye constantly on the watch for hot bearings, and upon the oil cups, the steam gauge, and the water glass; he must be attentively alert for strange sounds, knocks and thumps upon the engines, and with a little experience he will be able to tell at once what may be requiring attention, both by his sense of smell and hearing.

Knocking and Thumping on the Engines.—If there is any thumping upon the engine when in motion and turning the centres, draw over the link a little, and if the thumping ceases and the engine runs smoothly, very probably the valves have too little lead, or there is not a sufficient amount of cushioning. This can be noticed when the valves are examined, and if there seems to be too little lead, the eccentrics may be shifted to give the required amount.

If there is too much lead in the valve of a single engine, it is difficult to get the engine to turn the centre. When moved very slow, the piston will go to near the end of its stroke and then return, refusing to turn the dead points.

A valve may have too much lead on one side and too little on the other, through a washer or liner being omitted when overhauling the valve gear, wear or alteration of the main bearings, shifting of the eccentric sheaves, etc. This may be noticed by just moving the engine and noting its behaviour when turning the centre.

To detect the Cause of Knocking.—Knocking or thumping of the engines may occur from several causes, but with a little experience with a particular engine, it may readily be known where these sounds emanate from, by the peculiar nature of the sounds. Water in the cylinders gives a peculiar crackling knock; tight pistons or want of lubrication, gives a scraping labouring kind of sound as if in distress; slack bearings and want of cushioning, makes an unmistakable quick rolling kind of knock, hot bearings cause a mysterious knocking, but as this is accompanied by a strong smell of heated oil, it can readily be found. Choked or contracted exhaust pipes and passages cause wheezing asthmatical sounds to accompany the passage of steam, and the rattle and drop of loose valve gear is unmistakable.

The Working and Regulation of the Feed.—Feel the feed pipe close to the check valve, to find if it is getting warm through any defect of the valve by passing hot water from the boiler, or from the pipe salting up and the valve setting fast.

The working of the valve can be heard if working properly, by placing the ear close to the pipe.

It is better not to adjust the feed by screwing down or altering the lift of the non-return check valve, but to regulate it by a separate cock on the suction side of the pump and to leave the check valve always free to open.

An escape valve being also fitted between the pump and the boiler, any accident from burst pipes or broken pump rods will be prevented if this plan is adopted.

Check valves are often tampered with by unscrupulous firemen who wish to show plenty of steam by keeping the water low, while they lounge and smoke in some corner; the valves are afterwards forgotten, and the pipes, etc., are damaged in consequence. These should on no account be meddled with, except by the one or leading engineer in authority; his orders in this respect should be strictly enforced.

The proper use of a feed escape valve is to ease the pressure on the pipes when overloaded, and *not* to regulate the feed, as is often supposed. The feed escape should not have any connection with any other pipe for the purpose of saving and returning the water passed through the valve; by such means the engineer cannot tell when water is escaping, which it is of importance to know; the valve is neglected its action not being seen, and the pipes thereby endangered. By having the valve open and exposed, more attention will be paid to the regulation of the feed; if overhead and out of ordinary reach all the better; it will be less likely to be meddled with, and the showers of escaping water, if hard pressed will ensure attention and the regulation at the right place, the cock on the suction side of the pump.

When there are two boilers joined by the one feed pipe, there should always be a non-return valve placed between them, to prevent the water running from one boiler into the other.

Sometimes the fires in one boiler, from cleaning, firing, or otherwise, will be burning brisker than the others, or from the situation of the steam pipe being more direct with one boiler, or from one boiler priming, etc., there will be a greater pressure on one than on the other, causing the water to syphon through the connecting feed pipe, raising the water level in one and lowering it in the other, creating considerable dismay amongst the occupants of the engine room. If the feed check valves are properly constructed, there will be less likelihood of this happening, but they are rarely found to be so; the bearing face of the valve should be a little below the level of the inlet to the boiler.

Priming.—Priming is violent ebullition of the water in the boiler, or, in homely parlance, it is the water boiling over. It may occur through the sudden relief of pressure by opening the communication to the engines, or by dirty water, too little water surface in the boiler for the amount evaporated, or the faulty locality of the stop valve. In many boilers it is often a mystery to the engineer, but at the same time is simply caused by irregularity in the mode of feeding.

When priming does occur, the water is liable to be carried over with the steam into the engines, and may cause serious damage to the cylinder or cylinder covers.

Priming is prevented by fitting an internal perforated steam pipe inside the boiler, with the endeavour to take the steam from as many

different points as possible, or by fitting wash plates at the water level, and by feeding, firing, and surfacing, regularly, and with a method. It is sometimes temporarily stopped by injecting tallow, but this should be avoided as it injures the plates.

A steam trap or cistern placed on the steam pipe between the boiler and engine, with baffle plates fixed inside, will contribute towards the prevention of the water carried over by priming reaching the engines.

To Avoid Priming.—To avoid priming it is necessary to carry the water at one particular height which experience decides to be the best for the boiler. Priming in many cases is due to the fault of the firemen.

If priming continues, blow down from the surface and pump in cold water.

To get underway when starting without priming is very desirable; as the hot water getting to the engines will wash the lubrication from the face of the valve, and the rubbing surface of the cylinder; and as it takes time to get a good and of lubricant evenly distributed upon a large surface, if the priming film washing process is repeated often, an amount of friction may take place during the interval, that may tear up and actually spoil the valve face or bearing surface. Upon starting, have the drains from the cylinders open and let them remain so for two or three turns of the engine.

Oiling.—The oil cup with the worsted syphon, is a cup with a short projecting pipe inside, through which is passed a few threads of worsted attached to a piece of copper wire, bent to go into the tube with one end, and dip into the oil with the other, the bend in the wire preventing the worsted from dropping down the tube; the long end of the syphon should extend down the tube a few inches below the bottom of the oil cup to insure its working, the end in the cup being loaded with a piece of lead; worsted syphons should be carefully looked after, and it is to be remembered that they will lubricate if the cups are full either when the engines are stationary or in motion.

If the worsted is too tight in the tube, or composed of too many strands, the oil will not run.

If too many threads and slack, the oil may syphon too freely and cause waste.

If too few in number, they may supply insufficient oil for lubrication.

From two to six strands are generally found sufficient for easy lubrication, but the quantity of oil admitted to a bearing will depend entirely upon the friction of that bearing, and a judgment must be formed accordingly.

The worsteds should be clean, free from any extraneous matter such as gummy grease from bad oil, also free from twist and knots in the threads.

Where no worsteds are used, place a little float in the oil cup, which will keep the oil from splashing about; this is more applicable to the engines of steam launches and high speeds.

The oiling must be done periodically, say every hour, and a little at a time.

Tallow Cups.—Tallow cups for the cylinders of high-pressure engines are made with two small cocks; the cup is filled with oil or melted tallow with the bottom cock closed; the top one is then closed and the bottom one opened, so as to admit the oil without allowing the steam to blow it out.

Cups for cylinders of condensing engines have only one small cock, or one large hollow plug cock.

The cup is filled with tallow, and the cock opened on the up stroke or vacuum side of the piston, and closed again on the down stroke or steam side before turning the centre and admitting steam.

In some engines, when the best cylinder oil to be had is used, the tallow cups are discarded altogether, tallow not being required.

The best oil for cylinders is Valvoline, or oils containing glycerine; for bearings, Olive, or Gallipoli oil, in some cases Castor oil.

The Impermeator.—The Steam Lubricator or Impermeator, is an oil or tallow cup placed upon the valve chest, for the purpose of lubricating the valves and piston of the engine automatically.

It is composed of a large cup fitted with two internal pipes projecting upwards, one of them a little longer than the other; the long one is in communication with the steam which entering the comparatively cold cup, is gradually condensed; the water so formed floats the tallow contained therein, causing it to flow or drip through the shorter one into the valve chest.

Sometimes when it is wished to quicken the flow of tallow, cold water is thrown upon the exterior of the cup, thus condensing more steam and hastening its action.

Attendance in the Engine Room.—The engine room should never be left without some one responsible in attendance, as the moment is never known—unless perhaps when well out at sea—when the engines may require to be stopped and reversed, and that sharply.

Engines Racing.—In rough weather a constant stand by at the throttle valve will have to be kept, to check the engines when racing, unless a reliable governor is attached, which is seldom the case.

Hot Bearings.—If a bearing becomes hot, energetic action may have to be taken on the part of the engineer, and the hose applied to reduce it; many engineers refrain from playing on cold water as long as possible, on account of making a mess, but it is much better to put up with the mess than to have a regular hot bearing, especially a crank pin, when indefinable injury may be the result. If the bearings are fitted with white metal, the journal may become so hot as to melt and run the metal out, and perhaps drop the piston on to the cylinder bottom, an awkward affair to happen at sea. A bearing may get hot when little expected, especially in small craft where the engine room and stokehole are one in common, a current of air may waft a slight cloud of dust from the ash-pit or coal when firing, on to some of the bearing surfaces, and thus produce friction.

This should be guarded against, and the bearings felt occasionally with the hand, to ascertain if they are heating.

Sulphur and grease in combination is often used as a remedy, the fine metallic dust formed by friction when the rubbing surface gets hot, forms a sulphide with the sulphur, which becomes soft and greasy, and acts as a lubricant. The bearing should be deluged with oil before applying water, but if found insufficient, stop the oiling and play on the hose at once, endeavouring to play upon the shaft only as the brasses are subject to crack if cooled suddenly; at any rate the surface of the brass is liable to be so hardened as to throw off a scale which will cut up the journal worse than ever.

Objects requiring Attention in the Engine Room.—Warm bearings, the feed, the steam and water gauges, speed of engine, etc., are the principal objects of attention to the engineer, and if all these are favourable he may, excepting in rough weather, have but little to do. A great deal depends upon how the engines were originally fitted together, some give incessant trouble, while others sling away for months almost noiselessly, and require little attention.

Surfacing the Boiler.—If the run is a short one—which is most likely when yachts are in question—it is better not to surface the boiler during the time the vessel is under-way, unless the boilers prime, when it may become necessary.

The Temperature of the Feed from the Hotwell.—With condensing engines the feed should be put on as hot as possible without reducing the vacuum; this in a great measure will depend upon the particular machinery in hand, and a little experience will enable a judgment to be formed as to what is best for that particular pair of engines.

It is found to work well in some engines to introduce the feed water at 140 degrees, while the vacuum shows 25 inches, a better result being sometimes gained by working with a reduced pressure on the vacuum gauge, and so obtaining a higher temperature of feed water.

But care must be taken if the feed pumps are fitted with indiarubber valves, that the feed water is not hot enough to soften them. This will also apply to the air pump valves.

Heating the Feed.—With high-pressure engines, unless there is an exhaust tank and feed heating arrangement for the steam to be condensed in, it is as well to utilize it as a blast into the funnel. The feed heating arrangement has the advantage of doing away with the noise of exhausting direct into the atmosphere.

When feed heaters are attached to boats using fresh water only in their boilers, the exhaust steam should not mix with the feed water, but simply pass around the pipes on its way to the funnel, it often contains greasy matters deleterious to the boiler.

Feed Water Heaters.—Three square feet of heating surface per nominal horse power, is found to be amply sufficient to raise the feed water from 40 degrees Fahrenheit, to 212 degrees Fahrenheit, the temperature of the exhaust steam. The saving due to this, is a little over 14½ per cent. of the total amount of the fuel required to convert water at 40 degrees into steam at ordinary working pressure.

Pumps.—If the pumps are kept well packed, and the valves clean and in good order, with the usual amount of lift allowed of one quarter of their diameter, they will give little trouble. The pet cocks on the pumps should be tested occasionally, to be sure that the pumps are throwing water.

Air and Circulating Pumps.—The packing in the air and circulating pumps will last for a long time if well packed to begin with. If the buckets are fitted with rubber valves, these will require to be renewed frequently, especially if made of inferior rubber. Their life will depend a great deal upon the kind of oil used for lubricating the cylinders. Metallic valves are being substituted for rubber, with a considerable advantage in favour of economy, and quite as useful for the purpose.

Blowing Down at the End of a Trip.—When finished for the run or for the day, change the water in the boiler; pump it out if possible, but not before the boiler is well cooled down.

It is detrimental to the boiler to blow down with steam before the pressure is spent; and is prohibited in H.M. Navy. In merchant vessels the blowing down is usually done by opening the drain cock, and allowing the water to run into the bilges, from whence it is pumped overboard with the auxiliary or ship's pump. If no drain cock is fitted, slack back the gland of the bottom blow-off cock on the boiler, and lift or remove the plug; or slack back one of the lower mud hole doors, and thus allow the water to run out. This has the advantage of sweetening the bilges, which, from a decomposing mixture of grease and salt water, renders the exhalations anything but agreeable.

In steam yachts, excepting those of a large size, unless the water from the boiler is quite cold, the escaping vapour rising from the bilges may act detrimental to the woodwork and ornamental fittings of the vessel, and would not be agreeable to those who might possibly be living on board.

Changing the Water in Muddy Rivers.—Should the boat be moored in very shallow or muddy water, the changing of the water in the boiler might advantageously be defered until a more fitting opportunity arrived.

If the boat is very flat bottomed, and the feed pump suction from the sea, or the sea cock of the bottom blow-off, through which the boiler is run up is very low down towards the keel, it should be ascertained if the grating is free from mud or sand, otherwise an amount of dirt will be

drawn into the boiler, which it may be difficult to get rid of again, and may also be the means of causing annoyance with priming, and injury to the pumps and valve through which it may have to pass; any little grit may prevent the valves closing tight, and cause the pumps not to act.

Banking the Fires.—If the vessel has arrived at her destination, and the machinery is done with for the day, of course the fires will be drawn; but if again required, the fires may be banked, that is to smother them up with wet slack and ashes, closing the damper and leaving the fire-door and smoke-box door open. If the steam begins to blow at the safety valve when the fires are banked, pump up the boiler with cold feed water till the blowing ceases.

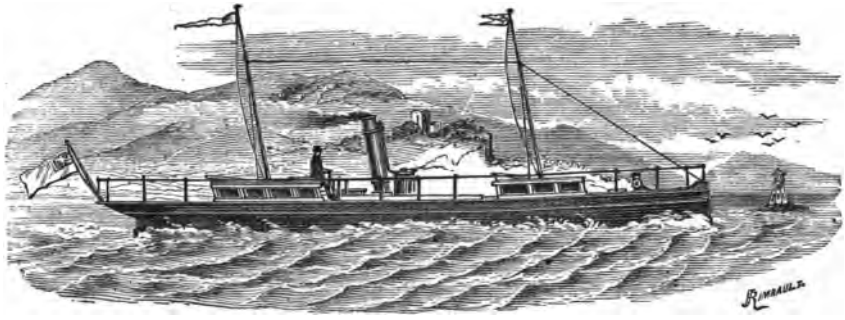
Precautions to be Adopted when Laying-up.—When the boat is to be laid-up for a season, the boiler should be emptied and thoroughly dried by placing a shovel full or two of lighted fuel in the furnace; leave off the manhole doors at top and bottom; shore up or take out the safety valve to allow of a free current of air passing through to prevent sweating; cover the top of the funnel to prevent rain or wet getting down to the boiler front. When the boiler is dry whitewash the inside with lime, which will assist its preservation. If it is found impossible to keep it dry, completely fill it with fresh water and put in a quantity of common soda.

All the packing should be drawn from the stuffing boxes and working parts exposed to steam, the oil holes and feeders to bearings plugged up with tallow or plugs of wood, oil cups filled with waste, and a piece of spun yarn wound round the shaft at the ends of bearing brasses, to keep out dirt and sand. If gratings are placed directly over the engine, endeavour to prevent anyone from walking over it and shaking grit and sand from their shoes upon the engines.

Give the engines a good clean down, then cover the bright parts with a coat of a mixture of white lead and tallow. The engines should be turned by hand about once a week, during the time they are laid-up, otherwise the piston and other working parts will corrode at the points of contact, and form an indelible ring round the cylinder, if moved occasionally this will be prevented.

THE STEAM LAUNCH.

In most instances the machinery of the Steam-Ship, Yacht, and Launch, are very similar in principle, the difference being only in size, speed, and when non-condensing or compound. The instructions given for one in many cases will also apply to the other, and the directions and information generally is common to all.



SEA-GOING STEAM LAUNCH.

In proceeding to get up steam in a launch, blow through the water-gauge glass, before lighting the fire, to be satisfied that the water level is all right, being certain about the height of water, next proceed to light the fire.

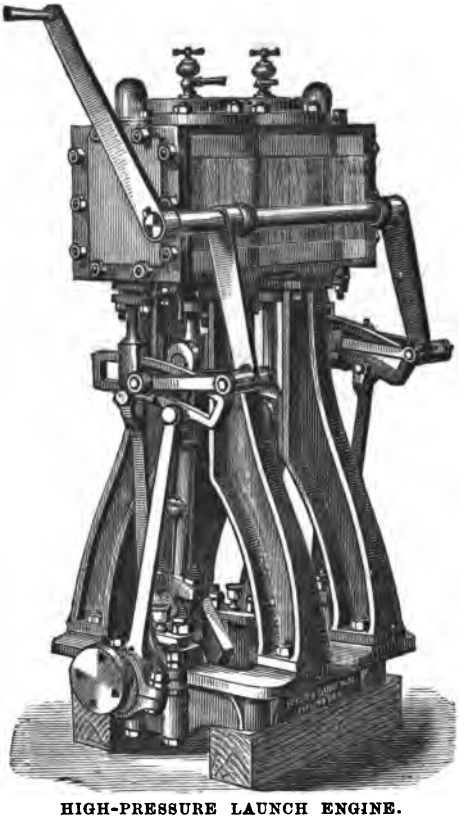
Have the safety valves opened as soon as the fires are alight, also the main stop valve, but as soon as vapour makes its appearance at the waste steam pipe, shut the safety valve and allow the steam to rise slowly to the required pressure, the steam blast for forcing the fire, should only be used for raising steam in cases of emergency or great haste.

Keep the stop valve or valves open to allow the steam to pass gently into the engine or engines, so that the metal may be heated up gradually, and so prevent accident from expansion.

If the construction of the boiler is such, that the fires or flame does not strike on the lower parts or shell of the boiler, be careful to have the boiler filled with water to, above the working height, and as soon as there is a pressure of 8 or 10 lbs., per square inch, shown on the boiler steam gauge, blow the water out till it comes down in the gauge glass to the working height, this will cause the lower parts of the boiler to get heated up and so prevent any straining or cracking of plates taking place, through unequal expansion.

Care of the Boiler while under Steam.—Supposing now that the boiler is thoroughly at work, the most careful and constant attention will be required while steaming.

As it is nearly always the boiler in Steam Launches that gives trouble, and as that is the most vital part in connection with the machinery, and the part that any danger may be particularly looked for or expected, it necessarily has given it the most prominence in these instructions.



HIGH-PRESSURE LAUNCH ENGINE.

Although the indirect causes which tend and may ultimately lead to accident are numerous, yet by looking into and examining the nature of a few of the most fruitful, the attendant may not only be prepared, but by using certain precautions he may avoid such to a great extent.

The first and perhaps the most prolific source of accident to ordinary launch boilers takes place through deficiency of water. There are a

multiplicity of circumstances which if not guarded against, may cause accident from this source.

So care is necessary to have the water gauge in a position where it can be easily seen, and the cocks readily handled; blow it through frequently, every hour at least, as also the gauge cocks which act as a check upon the glass.

The necessity of trying the Water Gauge.—In the case of small boilers and when the water is dirty, it is of the utmost importance that these necessary fittings should be frequently tried, as it is only by a watchful eye and assidious care, that a deficiency of water can be detected in time.

Uncoupling the Engine to work the Pumps.—It may be mentioned here that in the case of steam launches, it is a good plan to have the engine or engines made to uncouple from the screw shaft, so that the power may be used exclusively to work the pumps, if required to fill up the boiler in the case of emergencies.

The Feed Pump unworkable.—If the feed pump refuses duty, the valves must be taken out and examined at once, when it will generally be found that a small chip of wood or piece of grit underneath the suction valve has been the sole cause of the pump not throwing water, should this be not found to bring the water level up in the gauge glass, then a search must be made for a leak, which may be found either in the boiler, or in the coupling joints of the feed pump pipes, or in the feed pipes themselves.

Disapearance of the Water in the Gauge Glass.—Should the water go below the bottom gauge glass, draw the fires at once, and leave the furnace door open, also leave the boiler undisturbed for a short time, to allow it to cool down a little before adding any water, the plates become much weaker and less able to withstand the internal pressure, when overheated to any extent, also reduce the steam pressure gradually, this may be done by working off the steam with the engines, or by opening the safety valves gently, the latter course is preferable as the engine will require to be stopped to examine the feed pumps.

The Furnace Crown Hot.—In an extreme case when the water gets so low, that the tubes or furnace crown are bare of water, and observed to be heated to a cherry red heat, or altered in shape, do not attempt to draw the fire, but throw on wet ashes and slack, open the fire door and smoke box door, and close the damper. If the engines are working, keep them working, and let them work themselves out, but if stationary do not start them, or open the safety valve, but allow the boiler to cool down and reduce the pressure of its own accord gradually. Opening the valves or starting the engines, might produce a commotion in the boiler and cause rupture, also in the act of raking out a solid fire considerable heat is expended, tending to generate more steam and increase the danger.

When the heated plates are cooled down, the fire may be drawn and any pressure blown off as before; the boiler will have to be emptied and examined, if the plate is not burnt or seriously out of shape, when the cause of the accident is discovered and remedied, re-fill the boiler and start afresh.

The Fusible Plug a necessity.—The fusible plug is a useful automatic contrivance, applied to save boilers from accident through a deficiency of water. It is now extensively fitted to boilers of steam launches, and should be fitted to all small boilers, both afloat and ashore, as an additional precaution and safeguard against accident.

The fusible plug is a hollow brass socket, screwed into the plate on the top of the fire box, a smaller socket is screwed into the fixed one, the hole through the small one is filled up with an alloy, composed principally of lead, with a little copper added to harden it, which melts at a low temperature; immediately the water level falls below the plug and leaves it uncovered, the alloy melts, and the steam issuing through the socket puts the fire out, and gives warning most effectually.

It is then only necessary to blow away the steam and refit a spare plug —there should always be a couple of spare plugs carried in the boat. After filling up the boiler with the hand pump, proceed to light the fires, attending to the previous directions when raising steam. Should there be no hand pump fitted in the boat, fill up the boiler through the safety valve orifice, or take the top door off and fill up with buckets.

Fusible plugs should be scraped and cleaned on both sides frequently, and occasionally renewed, as they are liable to become useless after being exposed to boiling water for a length of time, a hard skin forms on the surface and intervenes between the fire and the plug, protecting the alloy and preventing its action.

Excessive Pressure.—Another fruitful source of accident arises from over pressure, to guard against casualties taking place from this, it is particularly desirous that the safety valve should be trustworthy and of good design, that is free from cross bars, bonnets or stuffing boxes, which all tend to impede the free action of the valve. The plain open topped safety valve is decidedly the best for providing against over pressure.

The Salter spring valve is of this description, and very seldom goes wrong, there are several others of a similar nature, both spring and weighted lever valves; spring valves are preferable as they are not affected by the pitching and rolling of the boat. Although it is more difficult to tell by calculation if a spring valve is correctly weighted, still it can be compared with the steam pressure gauge if the gauge is known to be correct, which can be ascertained if the index runs back to zero when relieved from pressure, or it can be actually tested with weights.

Periodical Tests.—It is important to know how far it is safe to weight the valve, for the strength and condition of the boiler for the time being. It is a good plan to test the boiler periodically, say every six months, with

water pressure to twice the working pressure as a precaution against accident. A working pressure of 40 or 50 lbs. is generally sufficient for the ordinary purposes of a steam launch, though most of launch boilers when new are capable of carrying pressures much higher. Boilers often deteriorate rapidly and their original pressures have to be reduced accordingly.

Care of the Safety Valves.—It is necessary that the safety valve upon which so much depends should be kept scrupulously clean, and also, that the action of the valve should be tested occasionally, and especially after getting up steam; by easing or raising the valve.

If in opening and closing it is found to act properly, a feeling of confidence is created, but as the most perfect mechanism will sometimes get out of order, it is advisable to have the boiler fitted with two safety valves, the one acting as a check upon the other.

The Steam Gauge a check on the Safety Valve.—The next fitting or mounting in the order of importance is the steam pressure gauge, a good gauge is a reliable check against any failing of the safety valve, as well as a register of the actual pressure in the boiler.

A gauge to be depended upon should be sensitive, and register any excessive pressure arising from undue weighting, defective safety valve, or improper tampering with the valve.

If a Bourdon steam gauge is used, the glass on the front, also the cover for the back of the gauge must be protected from the spray, if any heated vapour finds its way into the gauge, the cold spray on the outside causes it to act as a condenser, and keeps the internal parts moist and wet injuring the steel pins and pivots of the internal mechanism.

Protection of the Water Glass.—The water gauge glass should also be protected by a screen of some kind, from the spray washing over the boat, a dash of cold water upon the glass when heated is almost certain to break it. And the breaking of a glass in a small launch where there is not a great command of space—if it occurs at a critical moment—may lead to awkward results, such as when steering through crowded shipping or contending with strong tidal currents, &c., and may cause confusion and the loss of control of the boat for a few moments, until the cocks can be shut and a new glass fitted; this is another reason why the cocks on the gauge should be frequently tried, accidents of the above nature have occurred, when it was found that the cocks were set fast and could not be closed, serious consequences being the result.

Incrustation of the Boiler.—Accidents may arise from leakage, incrustation and corrosion of the boiler, the part of the boiler most likely to suffer from incrustation is the tube plates, and as a natural consequence the tube ends get burned and start leaking, salting up everything around them, besides causing an extra supply of water to be delivered into the boiler.

There is no remedy if the tube plates are dirty, but to take out the tubes and renew them, at the same time removing all scale and dirt from the tube plates.

In fact if incrustation is found to exist in the boiler to an injurious extent it must be removed at once, either by taking out the tubes, or by the use of cleaning tools,—the slice and scaling hammer—or by injecting into the boiler a small quantity of muriate of ammonia about $1\frac{1}{2}$ ounces twice a week, which will be found to loosen the scale, and so allow it to be removed with the tools, and the boiler thoroughly cleaned.

Corrosion of the Boiler.—If internal corrosion is found to be going on in the boiler, from the impurities resulting from the use of fresh but dirty water, then the whole of the inside of the boiler below the steam space should be coated with portland cement mixed with a little litharge and linseed oil, this will close the pores, or open fibre of the the iron: and effectually prevent the water from corroding the plates.

This is also a capital precaution to adopt with a new boiler when fresh water of doubtful character is to be used. It is also advisable to blow out a little from the bottom, say twice a day, as the solid matter settles in that part of the boiler.

The Density of Water in the Boiler.—If salt water is used, do not allow the density to rise over 30 or $\frac{30}{32}$ s, by the salinometer, commence to blow down at this density, as little as possible at a time, so as to maintain the water steadily at, or a little under $\frac{30}{32}$ s, it will be found that the deposit will not be so heavy on the plates of the boiler, as it would otherwise be by working the water at a low density, and so making it necessary to blow down a great deal more water.

It is a good plan to fill up the boiler in the morning with fresh water, making good the waste by using sea water, it will then be found to take nearly a day before the density rises to 25° or $\frac{25}{32}$ so that this method recommends itself, as it reduces blowing down to minimum.

Corrosion of Boilers when not in use.—It may also be mentioned here that as corrosion may take place in any boiler when not in use, and particularly in boilers of steam launches, where there is often no covering or protection from the weather, causing the plates to remain in a moist state, it will be apparent that it is imperative that the boiler should be kept dry both outside and inside,—iron surfaces will not rust in dry oxygen—this can be easily effected by having the boiler well covered, and by burning a piece of wood and a few shavings in the furnace occasionally, taking care to burn only sufficient to absorb the moisture and warm the air inside of the boiler.

External Corrosion.—If the outside parts of the boiler be accessible, as is usually the case at least with boilers of the locomotive type, there is not much to fear from external corrosion, only it should be kept well

scraped and painted. When the arrangement of the launch and boiler allows of it, it is advisable in all cases to cover the boiler with a clothing of felt and afterwards with wood lagging to retain the heat, and save fuel.

Care of the Boiler.—It must be remembered that although any individual boiler in question may be a thoroughly good one, or even an entirely new one, and the necessary appendages all that can be desired, yet these alone will not provide against accident unless used in a careful and intelligent manner and also kept in good working order.

Loose Nuts, Cottars, Etc.—Before starting the engines of a steam launch, check all the nuts of the several working parts; any nuts slacking back in an out of the way place may cause a break down.

Cottars and pins working slack has been a great cause of annoyance in many high speed engines. The gib and cottar joint should be discarded in the main working parts of the engines, they being long out of date and quite inadequate to the requirements.

Firing.—The desideratum in firing is to fire regularly and a little at a time.

Some fires require more attention than others and they may not always burn down level, which is owing to uneven fire bars, and the air spaces being wider or more open at some places than others, or if some of the lower tubes are stopped up with cinders or soot, the fire underneath them is not forced so much as the portion lying directly in the way of the draft. When the tubes extend low down at the sides of the flue they are likely to become useless, as the flame always takes the most direct course, and a few clean tubes in the direct line over the fire may do all the work.

The best shape for a fire in a small locomotive boiler is to have it concave, or what is called a hollow fire, with the larger pieces of coal round the sides, and thin with small coal in the middle; this form keeps the cold air from striking the sides of the furnace and allows it to become heated before passing through the tubes, all the air admitted to the fire should pass through the bars unless in cases when it is more desirous to prevent smoke than to raise steam, when a portion may be admitted through the fire door, over the fire, or at the back of the bridge; a fire should not be too thick, as the draft is then not able to draw sufficient air through the bars into the furnace for complete combustion, and the fire will burn sluggishly and probably die out. It should not be too thin as the air then will pass through too freely, cooling the furnace and tubes, and fail to keep up steam. In such a case throw a shovel full of small coals over the thin parts, so that the cavities where drawing air may be filled up.

There is a considerable art in firing, which most firemen fail to perceive, unless they have been thoroughly trained under engineers who knew their business.

Scientific firing as practised in competitions at Agricultural Shows, is quite an acquirement, the coals being chiefly put in by hand, little and often,

every gust of wind, and draft of air being studied, so that the fire door be opened at the right moment and as short and sharp as possible, just the amount of coal and air admitted to form a complete combustion, and no more, and the result is wonderful.

A little of the same kind of firing practised in steam launches would not be amiss, at least the result in steam, speed, and the saving of fuel would show for itself.

The mode of firing small locomotive launch boilers, is to place a shovelful of coals in each corner of the fire box, thrown in from the shovel direct, then a shovelful at the sides, back, and front, a portion of the coal will roll down into the centre of the furnace, thus shaping a hollow fire, thick round the sides and thin in the middle, this shape should be maintained, and once formed, should not be raked up or disturbed. When requiring to fire again, follow the same *rule* filling up the vacant places first, keeping the fire door open as short a time as possible. If some one were to stand by and open and close it just as the fireman was about to throw on the coal, so much the better. Endeavour as much as possible to prevent the wind blowing direct into the fire door when open, but fire when the door is to the leeward when it can be done.

On long trips without any stoppages, the fires should be well made up before starting with Welsh coal, if north country coal, break it up into nuts and throw some water over it before firing up.

Mode of firing Return Tube Boilers.—Vertical boilers are fired much the same as for the locomotive type. With return tube boilers and circular furnaces, each side is fired alternately and a shovelful or two thrown just inside the dead plate, and when thoroughly aflame it is pushed back with the rake, taking care to keep the bars covered.

Running short of Coal.—In the case of running short of coal and the bunkers expended, and the sweepings and dross from the bottom have to be used, a few lumps of chalk or pieces of fire-brick broken small strewed about the bars, will assist to prevent the small coal from falling through into the ash-pit, especially if the fire bars should be worn or irregular; this will enable a better fire to be kept up than otherwise could under the circumstances.

Quantity of Coal to carry.—To know the requisite amount of coal to carry, find out the quantity burnt per hour, say about 40 lbs: per hour for a 25 ft: steam cutter, and carry coal according to the length of time the run or cruise is likely to occupy. Have a small bunker fitted to hold about three quarter of a cwt., and carry the rest in bags, the coal when in bags is easily handled, and can be shifted as ballast if necessary, besides it keeps down dust in coaling, and is much cleaner throughout the run, than when coals have to be taken loose from under seats &c.

Shortness of Coal to be avoided.—Avoid any possibility of running short of coal. Nothing is more melancholy than the sight of a launch or

yacht in tow, in helpless inactivity through want of coal, a wonderful contrast to the state of things when all is right, and the launch a thing of life and spirit flitting about as it were full of energy and assertion in confident self-dependence.

Stern Tube Bearings.—If the launch should be running in a river such as the Thames or Mersey, the stern tube Lignum Vitæ bushes, will require to be examined whenever the boat is laid up, as the sand and mud works its way in and grinds the bush away rapidly, it can generally be known when this takes place, from a thumping sensation felt in the stern of the boat when under weigh. If there is any doubt about the stern bush not being sufficiently lubricated, the gland of the stuffing box may be slacked back to find if the water is circulating freely through the bearing.

Vulcanite is now coming into use for stern bush bearings, and is preferable to Lignum Vitæ, as it is more easily replaced when worn out, and will wear equally as well when exposed to a free lubrication of water.

Injector and Bilge Ejector.—For high speed boats, feed and bilge pumps worked from the main engines are better dispensed with, and a separate donkey pump, or injector, and bilge ejector, used instead; if this is done there will be less liabilty of derangement and breakdown when running at full speed. The best injectors are those that are most simple in construction having only one handle and one movement to put on or off the feed, and requiring no adjustment with varying steam pressures. Sometimes when the boiler primes badly it may become impossible to use the injector, from the water getting into the steam pipe when the boat rolls heavily in a seaway. When the steam pipe to the injector is carried sufficiently high, this will be prevented.

Precautions, when not in use.—Should the launch be laid up, remove the cylinder covers and valve casing covers, oil the sides of the cylinders, and the valve face, and replace the covers, this precaution will preserve the metal from rust. Coat the working parts of the engine with a mixture of tallow and white lead, and afterwards put a coat of paint over the top of the white lead and tallow, plug up the oil holes in the bearings and protect all bearing or rubbing surfaces with spun yarn from dust.

Also be sure that all the the water is removed from the pipes, the feed pump valve box, air pump, &c.

The Effects of Closing Valves suddenly.—Steam stop valves, blow off cocks, or valves of any description subject to pressure, should never be opened or shut off suddenly, by doing so the sudden arrest of the flow of steam, or the sudden relief of pressure is liable to produce a violent shock detrimental to the pipes and boiler. Incidents have occured where main steam pipes have been torn asunder from this cause, also safety valve chest covers lifted, and boilers burst when old and otherwise defective.

The bottom blow off cock is liable to stick when opened suddenly, the

sudden expansion of the plug through the difference of temperatures in contact with it, may cause it to stick so fast that it will be impossible to shut it again, until the temperature of the metal in the plug assimilates itself to that of the shell.

The blow off cock should only be partially opened at intervals, to allow the plug and shell to expand equally before being opened full.

The Elasticity of Steam.—Inexperienced persons are little aware of the amount of steam that will flow through a very small orifice or lift in the stop valve. Upon the trial of some experiments by the writer, with high pressure steam, it was found that a stop valve 4 inches in diameter, opening by a wheel and screw; when opened one-fourth of a turn of the wheel, or admitting steam at 120 lbs. pressure through an area of one square inch of opening or lift of valve, was sufficient to work a pair of 12 inch cylinders and indicating about 100 horse power.

A case of Accident through the Sudden Opening of a Stop Valve.—In an instance also under the writers notice, when a fireman ignorant of the foregoing properties of steam, had occasion upon the starting of a pair of engines to open the stop valve on the boiler.

The wheel on the valve was small and not of a good shape to get hold off, and the firemans hands being greasy, he unable to obtain a firm grip of the wheel, inserted a stick of about three feet long through the spokes, and gave the wheel a sudden sharp couple of turns, which this acquired leverage enabled him to do easily, with the following result. The steam pipe parted in two, a clean direct break out of solid metal, no other strain was upon it as it remained in perfect line and was otherwise not affected, there was also a bend of large radius upon the pipe, so that the break could not be charged to the expansion of the metal.

The Expansion of Pipes.—*Expansion Joints.*—Expansion joints are socket joints fitted to steam and other pipes subject to heat, for the purpose of providing for the elongation or expansion and contraction of the metal due to variation of temperature. They are most necessary in straight lengths of pipes where both ends are rigid and unyielding. If there are large bends upon the pipe, expansion joints are not required. Pipes are sometimes made purposely with bends to obviate the use of expansion joints; the give and take in a bend, with not too sharp a curve, being sufficiently elastic to allow for any expansion that may take place.

The socket part of the joint should be of brass, or lined with brass, at the bearing parts, also the loose end of the pipe entering the socket and the stuffing-box gland so that the working of the pipes may not be impeded by friction, caused by rust. The loose end of the pipe entering the expansion joint should in all cases have a flange, or two lugs, secured upon the pipe a short distance from the end, through holes in which, long bolts pass to corresponding holes in the flange at the stuffing box end of the socket, to provide against the pipe being blown out upon the admission of steam.

The bolts should not be screwed up tight, but left an inch or so slack to give free play to the working of the joint. In addition to expansion by heat, the pipes may have an amount of play owing to the working of bulkheads, &c., of the ship.

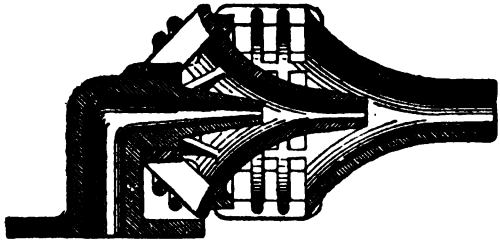
Very serious accidents have happened through the neglect of adopting the precaution of securing the pipe.

When an expansion joint is placed at an elbow where a flange cannot be applied, the bend or loose end should be stayed from some rigid structure or part of the ship.

Weir's Patent Hydrokineter, *or Water Circulator for Heating the Bottom of Marine Boilers.*—The unequal expansion, due to the great difference of temperature that high pressure marine boilers are subjected to while raising steam, is admitted by engineers and others connected with the working of steam ships, to be the sole cause of the leakage at the landings and rivets in the bottom of the boiler shell, and about the furnace landings below the fire bars. Any argument we could advance on the subject is therefore quite unnecessary. At the same time, we think it will be of some interest to give the results of some experiments made on a pair of boilers, 12 ft. 6 in. diameter, with 3 ft. furnaces in each. Cocks were fitted on the bottom of each boiler for drawing off water to ascertain the temperature in the bottom. The temperature in the top was got by drawing water by the salinometer cocks on the front of the boilers.

STARBOARD BOILER.				PORT BOILER (with ⅜ HYDROKINETER.)			
	TEMPERATURE.				TEMPERATURE.		
Time.	Top.	Bottom.	Difference.	Time.	Top.	Bottom.	Difference.
12-0 noon	40°	40°	0°	12-0	40°	40°	0°
12-30	46°	40°	6°	12-30	45°	43°	2°
1-0	54°	40°	14°	1-0	52°	48°	4°
1-30	80°	41°	39°	1-30	74°	61°	13°
2-0	122°	42°	80°	2-0	115°	87°	28°
2-30	179°	43°	136°	2-30	170°	141°	29°
2-45	206°	44°	162°	2-45	202°	172°	30°
3-0	219° Steam 2 lbs.	45°	174°	3-0	219° Steam 2 lbs.	200°	19°
3-30	301° Steam 50 lbs.	48°	253°	3-30	301° Steam 50 lbs.	Steam	

By comparing the difference of temperature between the top and bottom, and bearing in mind that the portion of the boiler shell, heated and expanded, is five times greater than the cold portion on the bottom, the reason that the bottoms get strained and leaky is easily understood. Indeed, it is astonishing that they stand so well as they do, for the expansion of iron due to 250° on an 18 ft. plate, is ⅜ths of an inch. Four-fifths of the boiler shell must therefore be lengthened ⅜ths of an inch, while the bottom is scarcely lengthened at all, and consequently the strain on the boiler must be far beyond the elasticity of the iron. Hence, it follows that the landings must either yield to the strain, or, what occasionally happens, the plates crack between the rivet holes, or even the solid plates give way.



Description of the Hydrokineter.—The Figure is a section of the three-nozzle hydrokineter. The flange of the first or steam nozzle is fixed on the inside of the boiler shell, and set in the direction the circulating current is to take. On this nozzle are fixed two outer or induction nozzles, and the back end of the one, and the outer ring of the other, are perforated to admit water between. Steam from the winch boiler is admitted by a check and stop valve to the steam nozzle, and getting condensed, throws a jet of water through the second nozzle. The volume of water is increased in passing through the outer nozzle. It then enters the bottom of the boiler and induces a current. The purpose the two outer nozzles serve, is more effectual to direct the force of the jet in the direction circulation is desired. When a steam jet is blown in openly, as the water gets heated to a certain temperature, the steam, on leaving the nozzle, expands and impairs the force of the jet. With the three-nozzle arrangement this is obviated. The water being directed on the steam jet, the steam is condensed between the first and second nozzles until the temperature of the water reaches about 170°. The outer nozzle then comes into play as a condenser, keeping the steam from expanding, and directing the jet straight into the water in the bottom of the boiler, until the pressure reaches that of the steam jet. The check valve now closes to prevent the water being forced back into the winch boiler.

Directions for Fitting-up and Using the Hydrokineter.—In single-ended boilers the hydrokineter is placed on the centre, at equal distances from the ends. With double-ended boilers, two hydrokineters are used, and placed one-fourth the length of the boiler from each end. The steam should be put on the hydrokineters when the fires (which may be hurried on if required) are lighted, but when the water approaches the boiling point the dampers ought to be closed, as the fires by that time are strong, and the temperature would rise very fast, if not in some degree checked. When steam shows on the boiler, care should be taken to allow at least 30 minutes for the steam to rise till it reaches the pressure on the winch boiler, so that the water in the bottom may be thoroughly mixed, and heated up to the temperature due to the pressure. By paying attention in giving sufficient time for the steam to rise till it reaches 30lbs., the hydrokineter will easily bring up the temperature of the water in the

bottom to 270°, using steam from the winch boiler at 30lbs. pressure. In very large steamers where there are a number of boilers, steam may be first raised on one, by the winch boiler and then the fires in the rest lighted, and the steam from it used to heat the others. In that case the steam jets may be made larger, so that the steam may be raised as fast as possible.

To Adjust the Slide Valves.—If the slide valve has got out of order through wear and tear of the joints, eccentric straps, etc., or from improper setting or other cause, they may be examined and re-set by the following process, the valve should when correctly set, have the top port just open to admit steam when the engine is at the top stroke, and the bottom port just open to admit steam when the engine is at the down stroke, this slight opening of the valve when the engine is on the centres is called the lead; or the admission of steam prior to the return motion of the engine. To find if the valves are properly set, it is necessary to find what is the amount and comparison of the lead, at top and bottom when the engine is at these points.

The crank of the engine in connection with the valve to be set or examined, is placed on its dead centres or in line with the piston rod, taking the top position first. The exact centres are found by squaring the crank with the guide face, or with the bolts in the connecting rod end, by dropping a straight edge from the guide face on either side, and placing the centre of the crank pin exactly between the two, the centre of the crank pin can be ascertained by measuring to the centre of the bolt ends in the connecting rod brasses. Or by scribing a line down the side of the connecting rod butt and cap, from the centre of the bolt heads to the centre of the bolt points on both sides of the crank cheek, when it can be seen at a glance if the sides of the crank cheek are parallel with these lines, or the distance between these lines may be measured or calipered at the four points, at the top corners of the crank, and at the lower edge of the connecting rod cap, if these four dimensions agree, the crank is central beyond a doubt.

Remove the valve chest cover, and place the go ahead eccentric in gear by throwing the link back. A fine tapered hard-wood wedge is then inserted into the port to determine the amount of *lead.*

The crank is now turned to its dead centre on the bottom stroke, and another similar wedge inserted into the opening of the bottom port.

The difference of the thickness of the two wedges when measured, indicate whether the valves are right or wrong. In small high speed launch engines the wedges should be equal, that is, the lead should be equal at top and bottom, usually about from $\frac{1}{16}$th to $\frac{3}{32}$nds of an inch.

In larger engines such as are used for small yachts the lead at the bottom is in excess of that at the top, and depends upon the angularity of the connecting rod, the speed, and the weight of the piston, piston rod, and cross head, which have to be lifted on the up stroke in addition to the work done by the engine, the lead at the bottom is often double that of the top $\frac{1}{16}$th of an inch at the top, and $\frac{1}{8}$th at the bottom. This of course can

be found accurately by calculation, but a comparative judgment can be formed of the proportion upon an inspection of the valves, sufficient for the purpose of the yacht or launch owner who may have no wish or time to go into the study of abstruse engineering. The lead is then equalized by adjusting the nuts on the valve spindle,

The same operation has now to be undergone with the go astern eccentric, with the link drawn forward. If there are a pair of engines, that is two cylinders and two valves, when one engine is made right the other may be examined similarly.

If on examination the valves are found to be so far wrong that the eccentrics require to be altered. To find their proper position, describe a circle on the forward end of the crank shaft, equal in diameter to the travel of the valve, a perpendicular line is drawn through the centre, the perpendicular line vertical with the engines being found, by squaring the shaft from the crank cheeks, draw also a horizontal line accurately at right angles to the vertical line, draw another line parallel to, and below, the horizontal line, equidistant to the amount of lap and lead, draw radial lines from the centre to the points where the lower horizontal line cuts the circle, those points will be the positions for the eccentrics, that is in the direction of their greatest throw, and the positions in which the key-ways have to be cut.

If a line be now drawn along the shaft to the part where the eccentric sheaves are placed, from the top of the vertical line on the end of the shaft, to the centre of the crank cheek, the positions for the eccentrics may be transferred to the proper position by means of a pair of calipers or compasses.

Previous to cutting new key-ways the valves should be tried to see that all is correct, the sheaves being temporarily fixed with set screws, or a hollow key rounded to fit the shaft. The sheaves are held fast in their respective positions by these means while the engines are being turned and the lead of the valves authenticated, always remembering that the eccentric in advance of the crank is the go-ahead one, unless a lever or wyper intervenes between the links and the spindle, for reducing the travel, which however is now seldom the case.

If the joints of the valve gear are much worn, allowance will have to be made in the lead for any slackness or play that there may be.

There is usually a simple arrangement of link-block, which can be lined up to allow for the wear of the crank journals and valve gear.

Setting Valves of New Engines.—The same mode of operation for setting valves may be adopted when setting the valves of new engines, only with the difference, that, instead of adjusting the nuts on the spindle, the eccentric rods are lengthened or shortened to suit, two centre punch marks being made on the rod, some inches apart, to clear the part to be heated, and these are gauged with a pair of trammels or compasses, so that the alteration in the length of the rod can be readily ascertained.

Internal Derangement of the Engines.—The engines may be in such a state of internal derangement that the cylinders may be passing twice as much steam through them as is required to do the work. In order to find out these defects, which may arise from several causes; a very common one is a leaky piston, in which case, the steam simply flows through the cylinder past the piston, and out at the exhaust pipe. This can be discovered by setting the engines in motion as slow as they will work, just sufficient to enable them to turn the dead centres, then listen attentively to the beating of the exhaust. This can be heard more distinctly if a foot-rule, or something similar, be placed between the teeth, the other end being held against the valve chest or cylinder. If the valve is properly set, and the piston is tight, each exhaust or beat will take place sharp and decisive at the end of each stroke. If anything is wrong with the valve the beating will be irregular, for instance, a short puff and then a long blow, this indicates at once that the valve is not set to exhaust, equally from the top and bottom. If, on the other hand, each exhaust is regular but indistinct, and followed by a constant or steady blow, one of two things is wrong, either the slide-valve is not fair on its face, and is passing steam into the exhaust port direct, or the piston packing rings are not tight and are passing steam through the cylinder. If the valve is passing steam it will be at once seen by placing the engine so that the piston will be near the extremity of its stroke, but not on the centre, or in such a position that the valve has just shut the steam port and opened the exhaust, then fix the engine in this position so that it will not move, turn on full steam, and if the piston is tight and the valve leaky, it will be at once seen by steam issuing from the exhaust pipe. If the piston is at fault it may be ascertained by placing the engine, and fixing it in any position at which it will get steam. If it passes the piston it will simply blow out at the exhaust pipe, where it can be at once seen. If the engines are condensing or compound, where the exhaust cannot be seen, admit steam to the top or bottom of the piston and open the oil cock on the cylinder cover, or the drain cock at the bottom of the cylinder. If steam is passing the piston it will be seen issuing from one or other of these cocks.

Stopping Split Boiler Tubes.—When a boiler tube splits and starts a leak in the boiler at sea, the readiest means of stopping it, is to drive a wooden plug into the tube past the leak, and another one in front of it, the wood of the plug swells when wet and will stand a considerable pressure, without blowing out. But tube stoppers are generally provided, of one description or other, which usually consists of a rod about the length of the tube, and flexible washers, the rod being inserted and screwed up from the front. When these appliances are not at hand the only means left, is to draw the fires to allow of a man passing through the furnace to the back tube plate, an ordinary rod being used, screwed at both ends, upon which is placed iron and canvas washers to press against the tube ends.

Tube plates sometimes become cracked between the tubes, owing to an accumulation of scale at those parts, which prevents the metal covered,

from expanding equally with the other portions of the plate, such cracks are repaired by fixing a piece of plate by means of screws over the crack and between the tubes, technically called spectacle eyes, or by drilling a hole at each extremity of the crack and inserting screwed pins, and caulking up the crack between.

Cleaning Boiler Tubes.—The boiler tubes should be periodically swept, as soot is a bad conductor of heat; clean tubes make a considerable difference in the economy of the coal consumption, the readiest way of cleaning tubes is to blow out the soot with steam, a piece of strong hose pipe, spliced to a piece of gas tube, being fitted and used for this purpose.

Water required for Evaporation.—To ascertain the quantity of water required to supply the boiler, approximately, when the consumption of fuel is known, the pounds of coal consumed per hour will be equal to the gallons of water evaporated per hour. Or when the grate surface is known and the draft is natural, the grate surface in square feet multiplied by 9 will equal gallons, and when the draft is forced, 50 per cent. will require to be added to give the number of gallons evaporated per hour.

Fouling of Condensers.—The inside of condensers and the outside of the tubes are apt to become foul with grease and tallow passed over with the steam, this is got rid off by blowing steam through amongst the tubes, or by injecting soda into the condenser. If the condenser is worked at a high temperature the tubes may scale up with salt on the inside also.

If the engines be worked with the common jet occasionally, it will assist greatly in cleaning the condenser from grease and impurities.

Condensation in Hot Climates.—In tropical seas, where the injection water is not cold enough to obtain a good vacuum, the hose is sometimes played with advantage upon the condenser externally, to assist the vacuum.

Indiarubber Valves.—Sometimes rubber valves have to be reduced in diameter after being used for some time; also valves have occasionally to be replaced by cutting the discs out of sheet rubber. If the knife, or borer, be moistened with a moderately strong solution of caustic soda and potash, indiarubber may be cut with as much ease as corkwood.

Packing the Piston.—Piston packing-rings should not be fitted too tight, this is a common mistake, causing unnecessary friction and drag upon the engine, besides leading to a cause of fracture in the cylinder, or split pistons.

Packing-rings, when well fitted, require only a pressure upon them of between 3lbs., and 4lbs., per square inch of their bearing surface to keep them tight, whatever may be the pressure in the cylinder. Ramsbottom rings

are often preferred for small cylinders, two rings being sufficient when a little broader than usual and over-lapped at the ends. Old pistons may be repacked with these, by replacing the packing-ring with a solid ring, grooved to receive the Ramsbottom rings, taking care that they are kept clear of the steam ports, otherwise the ring will spring into the port and jamb itself so that it will be difficult to withdraw it, if nothing worse happens.

The Steam Pressure Gauge.—The construction of steam gauges are various some having small cylinder and piston arrangements, connected with a link and segment of wheel to the index or graduated dial, the cylinder or tube communicating with the vessel or boiler in which the pressure is to be measured. The Bourdon gauge, however is the one that is most in favour and generally adopted.

The principle of the Bourdon gauge, is that of a curved metallic tube of a flattened form, communicating with the boiler at one end, and closed at the other; which end is connected with the index by an intermediate link, the whole enclosed in a suitable case.

The greater the pressure within the tube, it becomes the less curved, and so indicates on the dial the pressure within.

In other words it is a curved tube which the pressure endeavours to straighten, and in accordance with the force pressing within, becomes the more or less curved.

The pipe connected to the guage is made with a syphon bend to collect a small quantity of water, so that it may act as a cushion between the steam and working parts of the guage; also to prevent injury, as the steam permeating through the guage, would in time, spoil its action, and loosen the enamel from the dial, and also dim the glass so that it would become unreadable. There is a small cock sometimes placed on the pipe near the top of the bend, or in a position which, though not interfering with the action of the syphon, will prevent an accumulation of water, which in certain positions of a long pipe, might show an additional or false pressure of several pounds, quite foreign to the pressure in the boiler. These gauges are very sensitive, if in good order, but after a period of service there are comparatively few found to be correct to a pound or two, consequently they should be periodically tested, either with a Hopkinson's standard gauge made for the purpose, or a mercurial gauge, or by a column of water in a long pipe attached to a building or the mast of a ship,—one foot of water at 39° F. indicating .4355 pounds on the square inch.

Richard's indicator can also be used for this purpose: by fixing a cock on the boiler to suit the indicator cock, which is $\frac{3}{4}$-Whitworth's thread; attach the indicator, and draw the atmospheric line, open the cock to admit the steam to the indicator, and draw another line, which is the steam pressure line. Measure with the scale the distance between both lines; this distance gives the exact pressure per square inch on the boiler.

Compare the pressure gauge with the diagram thus taken, when it can be ascertained if they are working correctly.

It is rather difficult to know a good gauge from a bad one. However, when it is known that a gauge is good, great care should be taken of it; and it should not be used too long without cleaning, especially if placed in the stokehole, where it is often found that the lubricants of the working parts have dried up with the heat, and the friction considerably increased. They are also found occasionally to be choked in the socket with a kind of metallic mud or deposit, which may cause a serious deficiency in the indication of pressure: they are likewise affected by the salt, more or less. All gauges should be fitted with a blow-off cock, opening to the atmosphere, so connected that when steam is shut off, the index will run back to 0; and this used every watch will insure, the piping and gauge-tube being kept thoroughly clean. If the index should not go back to 0 when the steam is shut off, but still indicates a few pounds, that number of pounds should be deducted from the apparent pressure, to get the true pressure when steam is again connected. A great many gauges in use will act so. Others, again, will act in a flighty manner, showing a difference of a pound or two every day in the week. This is mainly caused by the roughness of the tube, imperfect fitting, and the quality of the metal in the flattened tube, which, if too soft, soon loses its elasticity; this is a very commom fault in cheap gauges. A new improvement is the introduction of the porcelain dial, upon which the permeating steam has no effect, and the dial always remains clean and readable.

Cocks on the pressure gauge, should never be opened suddenly, nothing deranges gauges so much as the violent shock caused by suddenly opening the communication to the steam pressure.

The Water Gauge.—The glass tubes used for water gauges, are specially drawn or made for the purpose from the hardest glass, and are consequently very brittle and liable to break on sudden alteration of temperature or lateral pressure. A glass will sometimes be no sooner fixed than it will crack, and have to be removed, which will be repeated again and again with like results; at last one may be found that will stand; and this particular one may remain intact for three or four voyages, until it requires to be taken out and cleaned; however as soon as replaced and communication opened to the boiler, away it goes into splinters in a most annoying manner. There are several ways of accounting for its breaking. It may have been caused by an undue side pressure in the packing, or a difference of temperature between the glass and the cocks when put in, or it may have been cleaned by washing in water—which they should never be—but cleaned with dry cotton waste or a sweat-cloth.

When a glass requires cleaning, take a piece of twine, make a loop at one end, and pass the twine down the bore till it projects at the other end; put a bit of cotton wick or clean cotton waste twisted a little, into the loop and pull it through the tube, which repeat as often as it may require, taking

care that it is not put in too tight, as the possibility of a little taper being in the tube it may get fast, and if the string breaks it will be a difficult job to get it out again.

A piece of cane with lamp wick wound round it, is useful in cleaning them; a wire should not be used, as by so doing glasses will often break.

When replacing a glass, care should be taken that it is not too tightly screwed up, especially if the new glass is a little larger in diameter than the old one.

A glass should not be fitted if there is less than $\frac{1}{4}$ of an inch for packing, there should also be a space between the glass and the brass washer or gland; if the metal touches the glass it will be sure to break sooner or later, owing to the unequal expansion of the glass and the metal.

When in its place, the glass should be allowed to remain a little till it gets warm before turning on the steam. Glasses in store, should not be allowed to rub in contact together, but should be kept wrapped up in the paper in which they are packed when bought from the maker, until they are wanted for use, and when taken out should not be laid down upon cold metal, such as the iron shelves of the store room or locker, or the flooring plates of the boiler room, and should be kept as free from scratches as possible.

There are many qualities of tubes in the market, the best are those made from the pure or virgin metal; inferior kinds are made from old bottles and other material, the vitality or virtue of which, is completely exhausted.

In the original process the glass is clear and brilliant; the others being charged with grit and specks, can be easily detected. There is a method of making the tube in one piece to any length required, and burnishing the ends, which resemble exactly the body of the glass in appearance; the rind or skin remaining thus unbroken commends itself, as evidently the glass will be more durable; but if in the manufacture these are cut from long lengths, and the ends only are heated and burnished, they will be as untrustworthy as the commonest of tubes; the anealing being unequal throughout, the expansion will vary considerably, when heat is applied, by the tube being opened to the steam.

Sometimes it is difficult to ascertain the water-level in a dark stoke-hole; and when the boiler is run up full, it requires a close inspection to know whether the glass is full or empty. The patent enamelled water-gauge glass has been got up to obviate this. The water in these patent tubes is reflected from a white enamelled strip in the back of the glass, showing the water quite white; the height of water can be seen at a distance, and in dark situations can be seen at a glance.

In all cases where there is any doubt of the water being out of the glass —if the glass is clean enough to enable the boiler-plates, or whatever is behind, to be seen through it—the fibre of the iron, spots of dirt, etc., will show magnified when the glass is full, the water acting in the glass as a powerful magnifying lens.

The Common Thermometer—*How to Graduate or Test its Accuracy.*—The common thermometer consists of a slender tube of uniform bore terminating in a bulb, containing a fluid such as alcohol, spirits of wine, or generally mercury, which expands with heat and contracts with cold, so that its surface in the tube indicates the degrees of temperature. As the bore is capillary, the mercury cannot be poured into it, but requires a particular process. But if the bulb is heated so as to expel a portion of the air contained therein, and the open end plunged into mercury, and the bulb cooled, the mercury will be driven into the bulb by the pressure of the atmosphere. The instrument must be again submitted to a high temperature by boiling, to expel the remaining air and moisture, and hermetically sealed; the latter is done by heating the end in a flame till the glass becomes soft, and twisting it so as to effectually close the aperture. If any inequalities are observed in the tube, allowance must be made in graduating. To graduate the instrument, place it in boiling water, or in steam under a pressure of 14 lbs. per square inch; the point to which the surface of the fluid expands in the tube, mark as the boiling point, next place the instrument in melting ice, and mark the point to which the surface of the fluid contracts, as the freezing point. For Fahrenheit's division, divide the interval between the two points thus obtained into 180 equal parts, and continue the scale upwards and downwards. Place 0 at 32 parts below the freezing point, 32 at the freezing point, 212 at the boiling point, and the other numbers of the series at convenient points as they may be required. The numbers express degrees of heat according to the position of the fluid.

For the Centigrade division divide the space between the freezing and boiling points into 100 parts—mark the freezing point as 0, the boiling point as 100 degrees, and so on as before.

The Reamur or Celcius division is divided into 80 parts, instead of 100 and 180 respectively as in Centigrade and Fahrenheit.

There are several kinds of thermometers made, according to the use they are intended for; the principal difference being the range to which the scale extends according to the degrees of heat to be measured. Those used in the engine-room of steam ships, for superheaters and receivers are graded from 190° to 360° Fahrenheit; and for feed-water heaters, from 60° to 230° Fahrenheit. These thermometers are fitted into a metal socket by a standard thread of screw so as to be interchangeable; the socket is bolted or screwed into a boss on the pipe or chest, etc., and is filled with mercury or oil, so as to give every facility for a steady indication.

If kept with ordinary care, their indicating may generally be relied upon, unless the scale from any cause becomes loose, and does not fit the tube.

If it can be found by comparison what the true temperature is, when the indication of a thermometer is suspected, whatever it may show at the point wanted, whether too high or too low, the difference will have to be added or deducted to give the correct indication, for instance if the thermometer shows 289° the true temperature being 330°; 289° will always

read 330° on or *vice versa* until the instrument is properly tested by a competent maker; if wrong, a new scale should be fitted upon the first opportunity.

The indication of thermometers alters with age if kept in constant use at high temperatures. In Thermometers used for feed-water heaters, the mercury will rise as much as one degree in twelve months; and in those used for superheaters etc., two degrees in the same period of time. The only way accountable for this rising of the mercury, is the contraction of the glass bulb of the tube.

The maker, whenever a thermometer has to pass through his hands for repair etc., always re-adjusts the scale before again sending it out, so that it may be expected to read correctly for twelve months to follow.

The Salinometer.—The salinometer is an instrument used for measuring the density of liquids, such as the water in the boiler. It is a bulb of glass, or metal, terminating into a graduated stem, and weighted at the bulb end with lead-shot or metal, sufficient to make it float upright.

By floating the salinometer in the water drawn from the boiler, its buoyancy depending upon the density of the liquid, thus indicates upon the graduated stem the degree of saltness of the water.

The water is drawn from the boiler through a cock fitted for the purpose, generally a little above the centre and between the furnaces—if there are two—into a copper can or other vessel; the water must be allowed to stand until its temperature—ascertained by a metal thermometer—is the same as that marked upon the salinometer, being the temperature at which, and for which, the instrument was made, generally 200° Fahrenheit.

The density of the water in the boiler should never be allowed to exceed $\frac{2}{32}$, the deposit of salt begins at $\frac{4}{32}$, the density of ordinary sea water being $\frac{1}{32}$, and the point of complete saturation when more salt cannot be dissolved $\frac{13}{32}$: a portion of the water contained in the boiler has occasionally to be blown off to neutralize the density, or in other words, by boiling down salt water the distilled or pure water evaporates in steam, leaving the sediment or salt behind which has to be blown off to prevent its accumulation.

The Salinometer is graduated or re-adjusted, by noting the points of flotation when placed into the extremes of pure distilled water and saturated salt water; these two points are marked on the stem and the space divided between. The instrument is then placed into a vessel containing common sea water and the point of $\frac{1}{32}$ marked, the water then is boiled down to one half its former bulk, and the point of $\frac{2}{32}$ marked upon it, and so on, the ballast or weight being added accordingly, care being taken to observe that there is no leakage.

When the salinometer gets broken or lost, a temporary instrument may be made with a piece of wood, a glass phial, or in fact, anything that will float and not absorb water.

However in modern practice, the salinometer is very little used, as the adoption of the practice of entirely changing the water, when in port,

dispenses in a great measure with the necessity of using the salinometer; frequent blowing off, causes a great waste of fuel, and it stands to reason, that the more water that is boiled down the more salt will be formed, also there are deleterious matters contained in the water, resulting from the oil and exudations from condenser tubes, rubber valves, etc., which the salinometer fails to show, and which are got rid of by changing the water entirely; scale also does not form to any greater extent than formerly, when the old practice was in vogue.

To find the Pitch of a Propeller by Measurement.—*When the vessel is in the Graving Dock, and the Propeller in its place.*—Place the blade to be measured in a horizontal position with the face downwards; at any convenient distance from the centre of shaft, say 4 ft. 6 in., place a wooden straight-edge across the face of the blade, and get some one to hold it in that position; then by sighting and marking where the line so formed (by the edge of the straight-edge) cuts the rudder-post at top, and the stern-post or keel, as it may be, at bottom; then measure the three sides of the angle so obtained—that is, from the mark on the rudder-post to the top of keel forming the perpendicular; from that along the keel forming the base; and the straight-edge on the face of the blade forming the hypothenuse; then find the circumference suitable to the diameter of 9 ft. The circumference divided by the perpendicular and multiplied by the base gives the pitch. It will simplify the operation if it can be imagined that the propeller is bolted on to the chuck of a lathe, and that the rudder-post is the face of the chuck.

Another, and perhaps a simpler method, is to take a piece of string and fasten a weight at each end—two nuts, for instance—throw it over the blade when in a horizontal position, with the face downwards, at any suitable distance from the centre of shaft. Measure from the bottom or leading edge of blade to the string which is hanging plumb, call that the *base* of the angle; the length of string itself to the following edge, the *perpendicular;* and the face of the blade, the *hypothenuse;* and proceed as before.

Example.—4 ft. 6 in. radius = 9 ft. diameter = 28.274 ft. circumference; suppose 7 ft. to be the length of perpendicular, and 4 ft. the base; then 28.274 divided by 7 and multiplied by 4 = 16 ft. 2 in. pitch nearly.

Should the propeller to be measured be lying on its face, on a level surface, the same *modus operandi* will do, provided that the circumference is divided by the base and multiplied by the perpendicular—the position of the sides of the angle being of course reversed.

Or, by any other suitable method form a right-angled triangle on the blade, at a given radius from the centre of shaft. The hypothenuse will represent the breadth of blade. One side must be at right angles, and the other parallel to the centre of shaft. Divide the circumference of the given radius, by the side at *right angles*, and multiply by the side *parallel*, and the result will be the pitch.

Stowage of Coals.—To ascertain the quantity of Coals that the bunkers will contain, the following rules will be serviceable. One ton of Welsh coal occupies 40 cubic feet; one ton of north country coal requires 43 cubic feet, for its stowage. The average of 27 kinds of coal gives 40½ cubic feet per ton

A simple and ready way to measure the bunkers, when calculating the quantity of coal they will contain, or the amount remaining in the bunkers—allowing 40 cubic feet per ton—is to take a rod or stick 3·4199 feet long, this is 3 feet 5 inches approximately, and divide its length by marks into tenths and hundredths; then with the rod measure the length, breadth, and depth of the bunkers, and multiply the three dimensions so obtained together in decimals, and the result will be tons. This is an easy and most convenient method.

Coal Test.—Coal containing the most carbon is the best, and should be selected, while coal containing an undue proportion of water or sulphur is bad, and should be avoided. Coal containing the most lead is richest in carbon, and by a very simple analysis, various kinds of coal can be tested and compared as to the amount of carbon which they contain. A small portion of the coal is powdered and burned in a crucible with litharge (protoxide of lead) in the proportion of 1 of litharge to 34 of coal. The contents of the crucible are covered on the top with salt, and the whole placed in the boiler furnace till burnt.

When taken out, a button of lead will be found in the bottom, which, shows the proportion of carbon according to its weight; the heavier it is, the more carbon there is in the coal.

The Best Steaming Coal.—A mixture of Welsh and Scotch or north country coal, is preferable for use in steam yachts, a proportion of two thirds Scotch and one third Welsh, and if possible, have the coal broken into pieces about the size of a man's fist. If the fire bars are kept well covered with this class of fuel there should be no difficulty in keeping steam.

Felt Covering for Steam Pipes and Boiler.—Hair next to feathers is known to be the most complete non-conductor of heat. Non-conducting or heat retaining felt is formed entirely of this material, chiefly hair from hides, and therefore by covering boilers, steam pipes &c. the radiation of heat is effectually prevented and the heat and power of the steam retained. The saving of fuel in many cases effected by felting amounts to about 25 *per cent.* In applying felt to boilers, a cement is made composed of the following ingredients :—

White lead	...	...	...	2	parts
Red „	...	...	...	1½	„
Whiting	...	...	...	4	„

The above is mixed with boiled linseed oil till the cement is about the consistence of treacle. The whole is ground until quite smooth, the cement

is then spread evenly on the side of the felt which is to be applied to the boiler, covering the edges of the sheet also with the cement.

The felt thus prepared is laid on the boiler and patted smoothly down, the cement sets in a short time and the felt adheres firmly.

If the felt is in a situation likely to be rubbed against, it is well to protect it with a covering of canvas or some similar material and painted over.

For steam pipes no cement is required, the felt is simply wrapped round the pipe and secured with twine, then covered with canvas and painted. Felt prepared as above will stand any amount of steam heat, and will prove a saving of fuel.

The Cash Value of Oils.—"That oil which allows the greatest heat to accumulate with the fewest revolutions must be a bad oil. The cost of the extra power required when a bad lubricant is used is very great. The heat produced on the bearing, costs as much as the coal costs, that will produce the same heat in the same amount of metal in a smith's fire; in other words, heat must not be allowed to reproduce itself, for, undoubtedly, if 20 degrees of heat above the temperature of the atmosphere are produced in a bearing, 20 degrees of heat are lost under the boiler, and the money lost for ever is the cash paid for the coal to produce that heat, and the cost of the extra wear and tear of the machinery."

THE MERITS AND DE-MERITS OF THE DIFFERENT TYPES OF ENGINES.

The Single Cylinder Engine.—Single cylinder, high pressure engines have the merit of occupying very little space, and the cubical contents of the space thus saved can be valuably utilized in larger cabins, greater cargo, or carrying capacity. They have fewer working parts than the double engine, therefore cheaper in first cost and less liable to become deranged. In all small engines the fewer parts or castings of which they are composed—bolted and jointed together—the better, and the less the liability of their becoming slack or out of order through the vibration of high speed. The demerits of the single engine are, that for reversing engines, which all marine engines are, they are difficult to start and reverse, and are liable to stick on the centre, and may have to be forced round by hand before the engine will move. A fly-wheel is generally required to help them over the dead points, which is not necessary in double engines. They have to be stronger than double engines, as the strain is more unequal upon the piston rod, connecting rod, and crank, especially if

worked at a high rate of expansion. In endeavouring to avoid this the steam may not be cut off early, then the engine will require nearly as much steam, or rather boiler power, as a double engine. In very small or plain craft, or for purposes where much manouvering or reversing is not required, such as barges on canals, &c., the single cylinder engine is of most advantage. For larger craft, especially sea-going boats, they are not generally to be recommended.

The Double Cylinder High Pressure Engine.—The merits of the double cylinder high pressure engine are, that the fact of having two cylinders and two cranks at different angles enables one of the cylinders at all times to get steam, one crank only can be on the dead centre at the same time; therefore the engines may be rapidly handled when stopping, starting, or reversing, a matter of the greatest importance at times in crowded rivers, harbours, &c., when a vessel may have to stop and reverse at a moments notice, and that sometimes in little over the boats own length. The pressure is more equally distributed over the main working parts previously mentioned, than in the single engine, whilst, being non-condensing, a condenser, air pump and circulating pump are not required, as becomes necessary in condensing and compound condensing engines.

Its demerits are, that as the cylinders exhaust into the air at atmospheric pressure, there is a waste of steam, consequently a waste of coal.

The beating of the exhaust into the funnel is disagreeable, and also emits soot, dirt, and sparks.

The Double Cylinder Condensing Engine.—The merits of the double cylinder condensing engine are that it is more economical of steam than the high pressure engine, as the advantage is gained of the vacuum formed by the condenser. Also, as it is worked at comparatively low pressures, it is not so severe upon the boiler. The boiler may be much lighter in construction, consequently much less in cost, and will last longer than with the high pressure or compound engine. It is comparatively simple and requires but little attention.

Its demerits are, that like the high pressure engine it is also wasteful of coal, though in a less degree. Full advantage is not taken of high pressures and the expansive properties of the steam, as in the compound engine. It is also more complicated and costly than the non-condensing engine, is of greater weight, and occupies more space.

The Compound Surface Condensing Engine.—The merits of the compound surface condensing engine are, the fuel consumed is only about one-half that required by the high pressure engine, and about three-fourths of that required by the simple condensing engine, to attain a given speed. It is more suitable, like the condensing engine, for working in salt water, as the condensed steam, after doing its duty in the engine, can be used fresh for the boiler feed.

The demerits, are their complication of parts, extra strength of metal, weight and cost, stronger and more costly boiler, a risk at certain speeds and pressures of putting all the strain on one piston ; also a risk, if the engines are not properly constructed, of not reversing to a certainty when wanted.

For very small engines the compound system is not of much advantage, as the saving of fuel would not compensate for extra trouble entailed, cost, complication of parts, and liability of getting into disrepair. For large engines they are universally recommended.

The relative merits of the compound engine, and common condensing engine, as deduced from various authorities and sources, are, that the consumption of coal on average long voyages is as 2 to 3; that is, if the condensing engine used 3lb. of coal per indicated horse power, the compound engine doing the same amount of work would only consume 2lb. per I.H.P.

The weight per indicated horse power, taking a fair average, is found to be 6·5 to 5, the compound engine being the heavier.

The Compound Non-Condensing Engine.—The compound non-condensing engine has the merit, though in a lesser degree, of the economical advantages of a high rate of expansion, as in the compound surface condensing engine, whilst the costly and cumbrous surface condenser, and air and circulating pumps, are dispensed with. It may be taken as a medium between the compound surface condensing engine and the high pressure engine, being not so economical as the one, nor so wasteful as the other. Steam is admitted into one cylinder and expanded in the other as in compound engines generally.

The demerits of this engine are the same as those for the high-pressure double engine, with the exception of the high rate of fuel consumption.

These engines are very suitable for medium sized boats; a connecting link between the class of boats driven by the small high-pressure engine and those larger driven by the compound engine, and where space and first cost is of import they are worthy of consideration.

In deciding the type and power of an engine to be placed into a boat. It must be remembered that the horse power required, increases or diminishes as the cube of the speed, so that a smaller engine will not diminish the speed to a proportionate extent, while a larger engine will not increase it largely, for instance to increase the speed from 10 to 11 miles per hour, requires an increase of 33 per cent. of the engine power.

Small Compound Engines.—We give on the frontispiece an engraving of a pair of compound screw engines of a type which has now become a favourite one for small powers in the Clyde district, suitable for a yacht of 200 tons, The particular engines illustrated are rated at 25 horse power nominal, and have been constructed by Messrs. Ross and Duncan, of Glasgow. The high-pressure cylinder is 13 in. in diameter, and the low-pressure cylinder 23½ in. in diameter, while the stroke of both pistons is 18 in. The surface

condenser forms the base of the back columns, being cast in a piece with them. It has a large cooling surface of solid drawn brass tubes $\frac{3}{4}$ in. in diameter.

The air, circulating, feed, and bilge pumps are worked by rocking levers from the crosshead of the low-pressure engine. The reversing gear consists of link-motion, and being of a size easily handled is worked direct by a hand lever. The general design of the engine is compact and substantial, and such as to admit of ready access to all the parts. All the rods are polished and have brass bushed joints easily adjustable.

Steam is supplied by a high-pressure cylindrical boiler 7 ft. 9 in. diameter, by 7 ft. 9 in. long, with two furnaces and return tubes. The total length required for engine and boiler space is abont 23 ft. This class of engine is altogether superseding the high-pressure non-condensing and the low-pressure condensing engines formerly so general on the Clyde, and of course effects a large saving in coal to the owners.

The results given by this class of engine are remarkably good, giving out a high indicated horse power, with easy pressure on the boiler, and the vacuum showing about $28\frac{1}{2}$ inches. This design of engine is made from 150 nominal horse power down to small sizes suitable for launches, for these latter however the stroke is generally shorter in proportion to the diameters of the cylinders.

The above mentioned firm also manufactures a new and special class of engine. The compound non-condensing engine, Duncan's patent. These engines have the great advantage of having no link motion reversing gear, or in fact any shifting gear for reversing the valves; each cylinder has only one fixed eccentric; by this improvement, the parts most liable to wear and tear are dispensed with. The engines work expansively, either compound condensing, or compound-non-condensing, and have also the economical advantage of being without condenser, air, or circulating pumps.

The compound-non-condensing engines seem likely to be much used in the future for all classes of work.

Non-Condensing Launch Engine.—The illustration on page 17 represents the "Clyde" type of launch engine, or, as it is generally called, the steam hammer type, that is with inverted cylinders fixed on to double cast iron standards or framing, The following are the principal particulars of the different items which, taken together, make up the complete propelling machinery required for the vessels for which they are suitable. Two inverted high pressure cylinders on steam hammer framing, the framing forming double guides, strong cast iron sole-plate, ribbed, or of the box form, according to the size; forged iron or steel crank shaft machined from the solid, gun metal bearings, adjustible brass sliders for the cross-heads, steel or case hardened link motion, arranged for high and variable expansion, and with lever and catch, or hand wheel and worm, as may be most suitable.

The feed and bilge pumps are worked by the main engines,—for high-speeds however a separate donkey pump or injector is generally used,—

the shafting is forged with solid couplings, gun-metal thrust bearing, brass stern tube, for small boats, and iron with brass bushes and *lignum vitæ* packing for large ones, propeller of cast iron, cast steel or gun-metal. The cylinders are lagged with felt and mahogany, and hooped with brass. Stop valves, grease cups, lubricators, &c., as usually fitted.

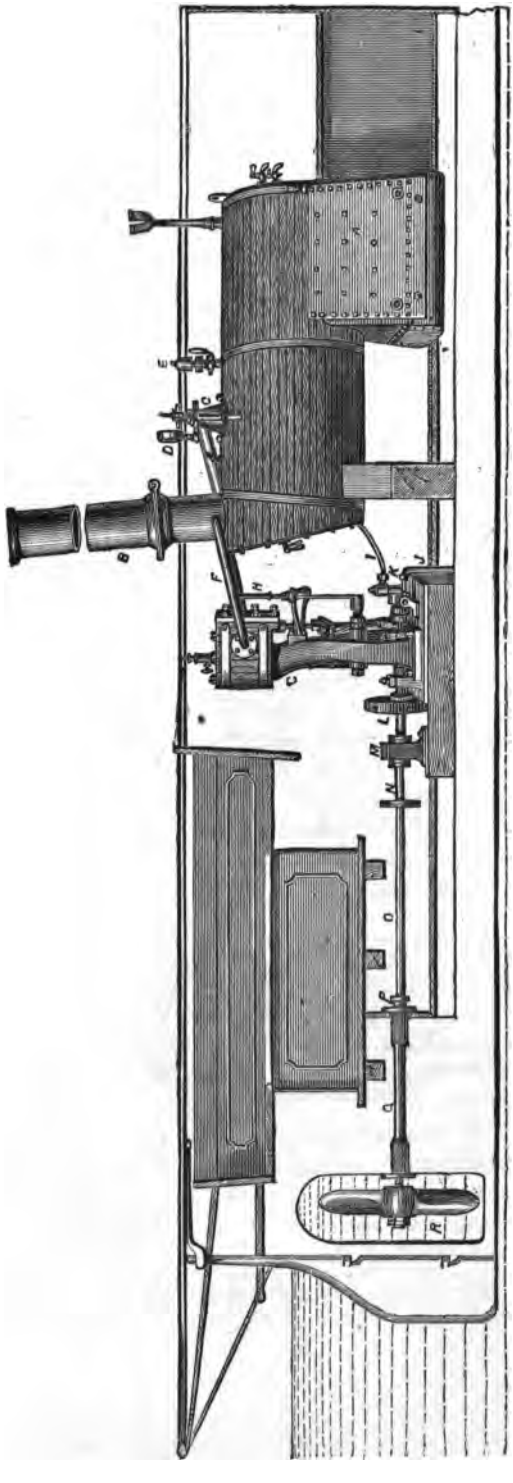
The boiler is of the locomotive horizontal tubular, return tubular, or vertical class. The following are the proportions of nominal horse-power, diameter of cylinders and stroke, of this type of engines, as made by Messrs. Ross and Duncan of Glasgow.

Nominal Horse-power, -	3½	5½	8	11	14	18	22	26	32	36	44
Diameter of Cylinders, -	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″
Stroke, - - - - -	5″	6″	7″	8″	9″	10″	11″	12″	14″	15″	18″

Arrangement of Machinery, with Single Engines.—The following woodcut shows the arrangement of the machinery of a steam launch, fitted with a 6 inch single cylinder engine and a boiler of the locomotive type; the stoke-hole being at the forward end.

The several most prominent parts are indicated by letters, as follows ;—

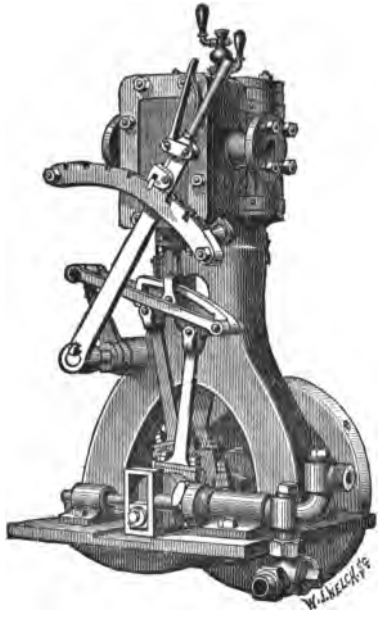
A.—Fire box of boiler.
B.—Funnel—hinged to fold down.
C.—Steam stop valve.
D.—Steam gauge.
E.—Whistle.
F.—Exhaust pipe leading into funnel.
G.—Engine framing.
H.—Reversing lever.
I.—Feed pipe to boiler.
J.—Feed suction.
K.—Feed suction cock.
L.—Fly-wheel, with lever holes for turning by hand.
M.—Thrust bearing.
N.—Crank shaft.
O.—Stern or propeller shaft.
P.—Stern tubes stuffing gland.
Q.—Stern tube.
R.—Propeller.



ARRANGEMENT OF MACHINERY OF STEAM LAUNCH, FITTED WITH SINGLE ENGINE AND LOCOMOTIVE BOILER.

The figure on the present page represents a single cylinder engine of the pattern made by MESSRS. A. WILSON & Co., London, suitable for the preceding arrangement. The diameter of the cylinder is 6 inches, and the stroke 6 inches. The cylinder is fixed to a box standard or frame, in one piece with the bottom cylinder cover, and the standard is bolted to a flat ribbed sole plate. The engine is fitted with link motion and locomotive reversing lever and catch, The feed pump is horizontal; worked from a crank at the forward end of the shaft, and is of very simple construction, having a three-way suction cock to draw from the sea, or from the bilge.

The engraving will give a general idea of the arrangement and design of

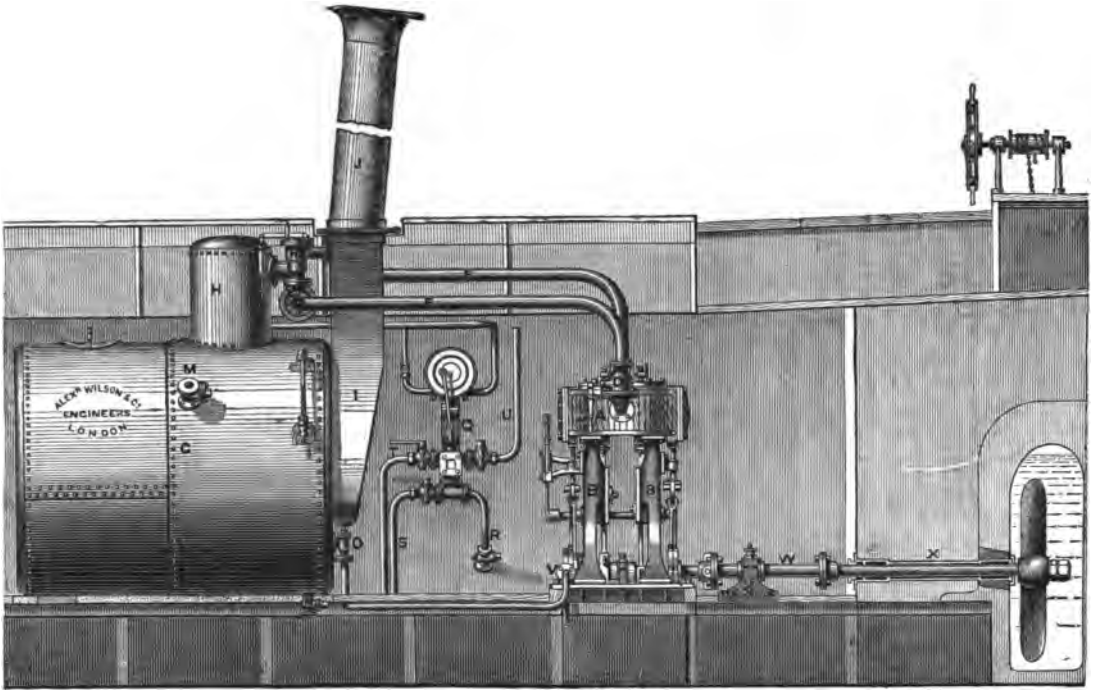


6 INCH SINGLE CYLINDER LAUNCH ENGINE.

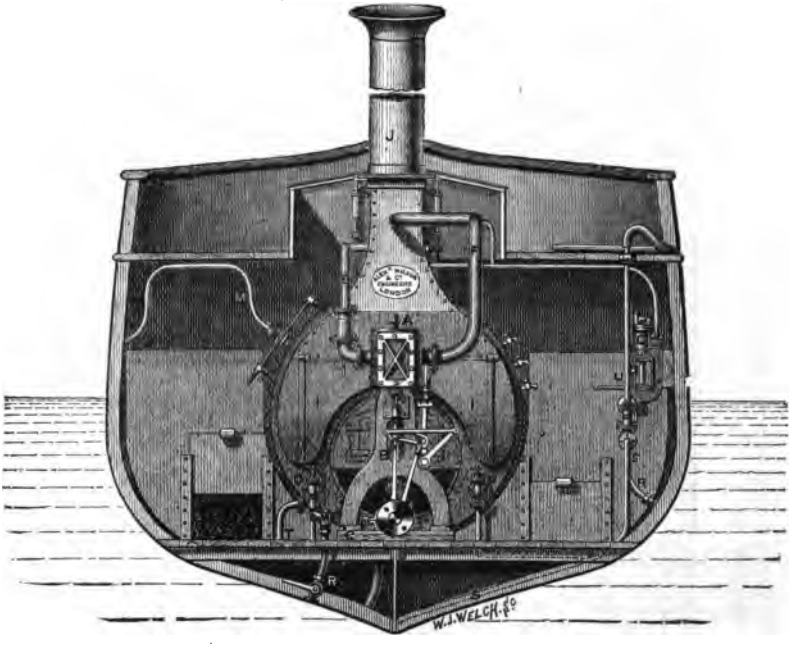
this class of engine, a small size of which has been said to have run 40,000 miles in two and a half years, without the attention of a trained mechanic.

TABLE of dimensions of boats, with the corresponding size of high pressure engines (single cylinder) to drive them; and the approximate speed in miles per hour;—

Length in Feet.	Beam in Ft. Ins.	Depth in Ft. Ins.	Approx. Draught Ft. Ins.	ENGINES.		Diameter of Screw Ft. Ins.	Pitch of Screw Ft. Ins.	Approx. Speed Miles Per Hour.
				Dia. Ins.	Stroke Ins.			
20	5 0	2 9	2 0	4½	4½	1 11	3 0	9
25	5 6	2 10	2 0	4½	4½	1 11	3 0	8
25	6 0	3 2	2 3	5	5	2 2	3 6	8
30	6 0	3 6	2 8	6	6	2 6	3 9	10
30	7 0	3 8	2 8	6	6	2 6	3 9	8½
35	6 6	3 8	2 8	6	6	2 6	3 9	9
35	7 6	3 10	2 10	7	7	2 9	4 0	10
40	7 0	4 4	3 3	7	7	2 9	4 0	11
40	8 0	4 4	3 3	8	8	3 0	4 6	11½
40	8 6	4 6	3 4	8	8	3 0	4 6	11
45	7 6	4 4	3 3	8	8	3 0	4 6	11½
45	8 6	4 9	3 4	9	9	3 3	5 0	11½
45	9 0	4 10	3 6	9	9	3 3	5 0	11
45	9 6	5 0	3 8	9	9	3 3	5 0	10
50	8 6	4 9	3 6	9	9	3 3	5 0	12
50	9 0	4 9	3 6	9	9	3 3	5 0	11
50	10 0	5 6	4 0	10	11	3 6	5 6	10
50	11 0	5 9	4 0	10	11	3 6	5 6	9
60	9 6	5 0	3 9	10	11	3 6	5 6	10
60	10 0	6 0	4 3	10	11	3 6	5 6	9½
60	10 6	6 3	4 4	12	12	4 0	6 0	10½
60	11 0	6 6	4 6	12	12	4 0	6 0	10
60	12 0	7 6	5 0	12	12	4 0	6 0	10
60	13 0	7 6	5 0	12	12	4 0	6 0	9
70	11 0	7 0	5 0	12	12	4 0	6 0	10
70	12 0	8 0	5 6	14	14	5 0	6 6	11½
70	14 0	9 0	6 0	14	14	5 0	6 6	11
70	15 0	9 6	6 3	14	14	5 0	6 6	10
80	12 0	8 0	6 0	14	14	5 0	6 6	11
80	14 0	9 6	6 6	14	14	5 0	6 6	10
80	16 0	10 0	7 0	16	16	5 6	8 0	11
80	18 0	11 0	7 6	16	16	5 6	8 0	10



LONGITUDINAL SECTION OF THE AFTER PART OF A BOAT, SHOWING THE ARRANGEMENT OF THE ENGINES. BOILER, AND PIPE COMMUNICATIONS.



CROSS SECTION OF BOAT, SHOWING THE ARRANGEMENT OF ENGINES, BOILER, AND PIPE COMMUNICATIONS.

Arrangement of Machinery, with Double Cylinder Engines.—The illustrations on the present pages show a representative arrangement of machinery and pipe connections as fitted into the after part of a boat. The arrangement is that of a pair of double cylinder high-pressure engines, and the cylindrical return tube boiler; of 14 nominal horse power.

The several parts are indicated as follows;—

A.—Cylinders of engine.
B.—Frames of engine.
C.—Bed plate of engine.
D.—Steam Regulator.
E.—Steam pipe.
F.—Exhaust pipe.

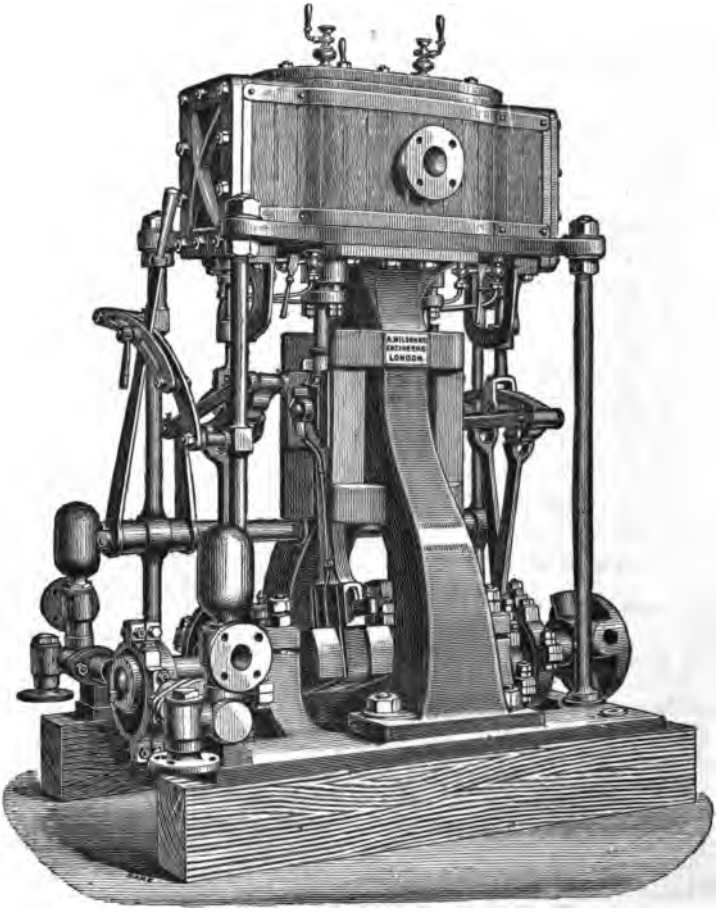
G.—Boiler.
H.—Dome.
I.—Smoke box.
J.—Funnel.
K.—Safety valves.
L.—Stop valve.
M.—Scum cock and pipe.
N.—Blow-off cock and pipe.
O.—Check valve for pump.
P.—Check valve for donkey.
Q.—Donkey pump.
R.—Cock and pipe from sea.
S.—Cock and pipe from bilge.
T.—Cock and pipe to boiler.
U.—Cock and pipe to deck.
V.—Feed pump on engine.
W.—Intermediate shaft.
X.—Propeller shaft and stern tube.
Y.—Propeller.
Z.—Thrust block.

The engine has a pair of cylinders 8 inches diameter, and 9 inches stroke.

The Boiler is 5 feet 6 inches diameter, 7 feet long, and contains 50 2½ inch tubes. The crank shaft is 3½ inches diameter, and the propeller 4 feet diameter, with a pitch of 5 feet. These views are drawn accurately to a scale of ¼ inch to the foot, and give an exact representation of the whole machinery as actually fitted into a boat, and will give an idea of the pipe connections, where they lead to, and where they lead from, and their several and respective uses. The owner of a boat or yacht of whatever description, should always have a drawing prepared of similar views of the machinery arrangement pertaining to his particular boat, which should be kept handy for reference at all times, in case there should be any doubt concerning the leading of the pipes, &c.

These views may also assist to make the probable purchaser of such boats &c., sufficiently familiar with the various parts of the machinery and the space occupied in the vessel, to enable him to form a judgment of the capabilities of the different designs or boats that he may have placed before him, and to decide accordingly.

This arrangement here shown may not be the best possible that could be devised, but it shows the number of pipes sufficient for the purpose, arranged in a simple manner; while more might be superfluous, or lead to more intricate complication which is often the case in pipe arrangements.



A PAIR 14 N.H.P. DOUBLE CYLINDER HIGH-PRESSURE ENGINES, CYLINDERS 8 INCHES DIAMETER, BY 9 INCHES STROKE.

The accompanying figure shows a pair of double cylinder high pressure engines suitable for the previous arrangement. These engines are 14 horse power nominal, with cylinders 8 inches diameter and 9 inches stroke. The design is that of Messrs. Alex. Wilson & Co., London, and the following table gives the proportions and particulars of such engines as

made by them, also with the dimensions of the corresponding boilers suitable for these powers, and the relative heating surface and weights.

TABLE OF DIMENSIONS OF DOUBLE-CYLINDER HIGH-PRESSURE SCREW ENGINES.

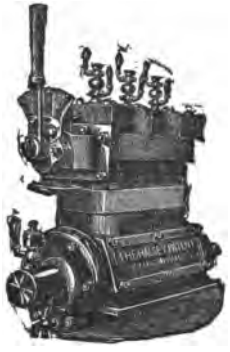
Nominal Horse-power		3	5	7	8	10	14	18	24	30	40
Diameter of Cylinder	inches	3½	5	6	6½	7	8	9	10	12	14
Stroke of Engine	„	5	6	7	7	8	9	10	12	14	18
Height over all	feet & inches	2 6½	3 4½	3 10½	3 10½	4 3	4 9	5 2½	6 0½	6 9½	8 4½
From under side of Bed Plate to centre of Crank Shaft	„	4½	6	6½	6½	7½	8½	9½	10½	11½	1 2
Length of Bed Plate on Keel	„	1 9½	2 3	2 7½	2 7½	2 9½	3 1½	3 6½	4 0	4 5½	5 1½
Distance from centre of Engine to face of Coupling	„	1 1	1 4½	1 5	1 5	1 7½	1 11½	2 1½	2 3	2 6	3 1½
Breadth athwarts	„	1 4	1 9½	2 0½	2 0½	2 3½	2 6½	2 10	3 2	3 7½	4 7½
Diameter of Crank Shaft	inches	1½	2½	2½	2½	3	3½	3½	4	4½	5
„ Steam Pipe	„	1	1½	1½	1½	2	2½	3	3½	4	5
„ Exhaust ditto	„	1½	2	2	2	2½	3	4	5	6	7
„ Pump Ram	„	1	1½	2	2	2½	2½	2½	3	3½	4
„ Propeller	feet & inches	2 0	2 6	2 9	3 0	3 3	4 0	4 6	5 0	5 6	6 0
Pitch of ditto	„	3 6	3 6	4 0	4 0	4 6	5 0	5 6	6 6	8 0	9 0
Diameter of Propeller Shaft	inches	1½	2½	2½	2½	3	3½	3½	3½	4	4½
„ ditto, if in Steel	„	1½	2	2½	2½	2½	2½	3	3½	3½	3½
Length of ditto to aft side of Propeller	feet & inches	6 0	6 0	7 0	7 6	8 0	8 6	9 3	10 0	11 0	12 6
Length of Stern Tube between Flanges	„	1 9	2 6	3 0	3 2	3 5	3 6	3 9	4 3	4 6	5 0
Diameter of Boiler	„	2 9	4 0	4 6	4 6	5 0	5 6	6 0	6 6	7 3	8 0
Length of ditto	„	4 2	5 6	6 0	6 6	7 0	7 6	7 6	8 0	9 6	9 6
Diameter of Flue	„	2 0 × 1 6	2 0	2 3	2 3	2 6	2 9	2 10½	3 2	Two 2 3	Two 2 4
„ Tubes	inches	1½	2½	2½	2½	2½	2½	2½	2½	2½	2½
Number of ditto	„	45	26	34	34	44	50	58	81	86	102
Diameter of Dome	feet & inches	1 2	1 6	1 9	1 9	1 9	1 9	2 0	2 3	2 6	2 6
Height of Dome	„	1 0	1 9	2 0	2 0	2 0	2 3	2 3	2 3	2 6	2 6
Total Heating Surface	square feet	29	82	115	138	186	240	300	356	541	614
Weight of Engine in cwts.		3½	7½	12	12½	15½	24½	27½	41½	63	95
Approximate weight of Propeller, Shaft, Stern Tube, and Thrust Bearing in cwts.		1½	2½	3½	4½	5½	7½	10½	12½	14½	19
Approximate weight of Boiler in cwts.		14	30	45	49	65	77	85	110	150	170

TABLE of dimensions of boats, with the corresponding size of high pressure engines (double cylinder) to drive them and the approximate speed in miles per hour.

Length in Feet.	Beam in Ft. Ins.	Depth in Ft. Ins.	Approx. Draught. Ft. Ins.	ENGINES.		Diameter of Screw. Ft. Ins.	Pitch of Screw. Ft. Ins.	Approx. Speed Miles Per Hour.
				Diameter. Ins.	Stroke. Ins.			
25	5 6	2 10	2 0	3½	5	1 11	3 6	9
25	6 0	3 2	2 3	4	5	2 2	3 6	9
30	6 0	3 4	2 6	4	5	2 2	3 6	9
30	7 0	3 8	2 8	4	5	2 2	3 6	8
35	6 6	3 8	2 8	5	6	2 6	3 6	11
35	7 6	3 10	2 8	5	6	2 6	3 6	10
40	7 0	4 2	2 10	5	6	2 6	3 6	11
40	8 0	4 4	3 3	6	7	2 9	4 0	12
40	8 6	4 6	3 4	6	7	2 9	4 0	11
45	7 6	4 4	3 3	6	7	2 9	4 0	12
45	8 6	4 9	3 3	6	7	2 9	4 0	11
45	9 0	4 10	3 6	6½	7	3 0	4 0	11
45	9 6	5 0	3 8	6½	7	3 0	4 0	10
50	8 6	4 9	3 6	6½	7	3 0	4 0	12
50	9 0	4 9	3 6	6½	7	3 0	4 0	11
50	10 0	5 6	4 0	7	8	3 3	4 6	10
50	11 0	5 9	4 0	7	8	3 3	4 6	9
60	9 6	5 0	3 9	7	8	3 3	4 6	10
60	10 0	6 0	4 3	8	9	4 0	5 0	11
60	10 6	6 3	4 4	8	9	4 0	5 0	10½
60	11 0	6 6	4 6	8	9	4 0	5 0	10
60	12 0	7 6	5 0	9	10	4 6	5 6	11
60	13 0	7 6	5 0	9	10	4 6	5 6	10
70	11 0	7 0	5 0	9	10	4 6	5 6	11
70	12 0	8 0	5 6	9	10	4 6	5 6	10½
70	14 0	9 0	6 0	10	12	5 0	6 6	11
70	15 0	9 6	6 3	10	12	5 0	6 6	10
80	12 0	8 0	6 0	10	12	5 0	6 6	11
80	14 0	9 6	6 6	12	14	5 6	8 0	12
80	16 0	10 0	7 0	12	14	5 6	8 0	11
80	18 0	11 0	7 6	12	14	5 6	8 0	10

TABLE of dimensions of boats, with the corresponding sizes of compound condensing engines to drive them:—

Length in Feet.	Beam. Ft. Ins.	Depth. Ft. Ins.	Approx. Draught. Ft. Ins.	ENGINES. Dia. Ins.	ENGINES. Stroke. Ins.	Diameter of Screw. Ft. Ins.	Pitch of Screw. Ft. Ins.	Approx. Speed in Miles Per Hour.
				High Low				
40	8 0	4 4	3 0	6 & 12	7	2 9	3 6	12
45	9 0	4 9	3 6	7 „ 14	8	3 0	4 0	12
50	10 0	5 6	4 0	8 „ 16	9	3 3	4 6	11
60	12 0	7 6	5 3	9 „ 18	10	4 0	5 0	9
60	12 0	7 6	5 6	10 „ 20	12	4 6	5 6	10
70	14 0	9 0	6 0	10 „ 20	12	4 6	5 6	9
70	14 0	9 0	6 0	11 „ 22	12	4 9	6 6	10
70	14 0	9 0	6 6	12 „ 24	14	5 3	7 0	12
80	14 0	9 6	6 6	12 „ 24	14	5 3	7 0	12
80	14 0	9 6	7 0	14 „ 28	16	6 0	8 6	14
80	16 0	10 0	7 0	12 „ 24	14	5 3	7 0	10
80	16 0	10 0	7 6	14 „ 28	16	6 0	8 6	12

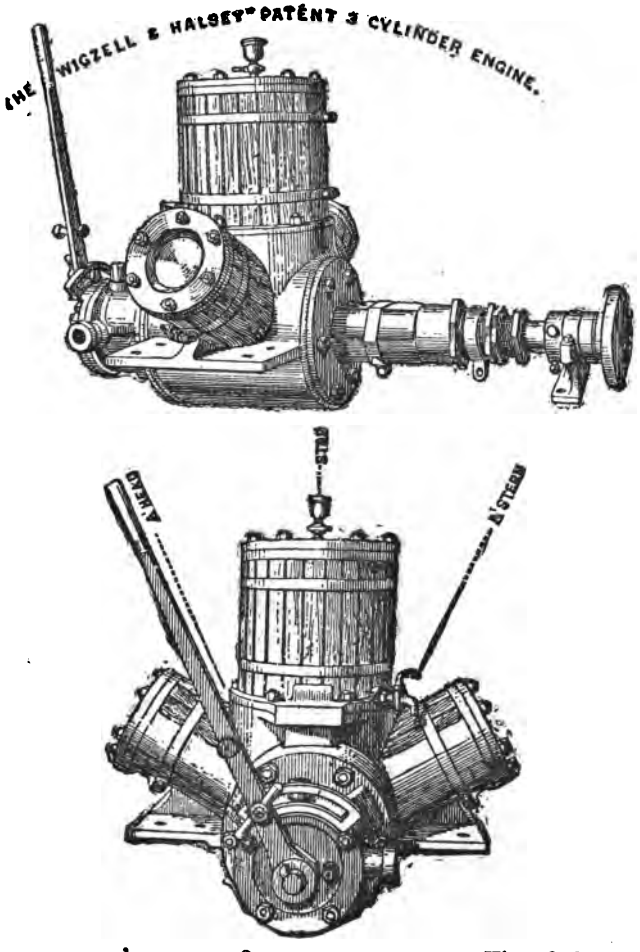


THE HALSEY 3 CYLINDER LAUNCH ENGINE.—Fig. 1.

The Halsey Three Cylinder Engine.—The illustration, Fig. 1, represents Halsey & Co's. patent engine for yachts, launches, &c., or for any purpose where it is necessary to start or reverse quickly, or at any part of the stroke. This form of engine is capable of instantaneous reversal whilst running at the highest speed. It has no dead centre, and steam can be cut off at any part of the stroke by means of the one lever which controls its motion, and by the same lever the engines can be converted from high pressure to compound. The pressure is always in one direction on the working parts, and consequently works perfectly noiseless, and may be run at very high speeds. The design of the engine enables

it to be placed very low down in boats of the finest lines. Steam is admitted direct from the boiler to the top of the piston; thus dispensing with the wire drawing of the ports and valves of common engines.

The illustration shows the position of the lever with the engine stopped and steam shut off; by moving the lever to the right or left the engine is turned ahead or astern as required. The working parts are encased and working in oil, the whole being of exceedingly simple construction. Figs. 2 and 3 represent another design of the same engine suitable for marine purposes.



HALSEY'S PATENT 3 CYLINDER ENGINE.—Figs. 2-3.

Sizes in Relation to Power of Three Cylinder Engine.

Nominal Horse Power	3	4	5	8		12		18	24	34	54
Indicated Horse Power	12	16	20	32		45		70	95	135	215
Revolutions per Minute	1000	900	900	850		750		650	650	600	500
Diameter of Cylinder in Inches	2½	3	3½	4	4½	5	5½	6	7	8	10
Length of Stroke in Inches	3½	4	4	5		6		8	9	10	12
Approximate Weight of Engines in lbs. ..	120	140	168	2cw.		2¾c.		4¾c.	6cw.	7¼c.	14c.
Length of Engine Bed in Inches	12	13	14	15		18		22	24	28	36
Width do. do.	10	11½	12	13		15½		22	42	26	28

THE WILLAN'S ENGINE.

In the Willan's engine, three cylinders are used; each cylinder is single acting, receiving its steam upon the upper side only of the piston. The connecting rods are attached directly to the pistons, and actuate a three-throw crank shaft. Each piston serves as a steam valve, and controls the supply of steam to one or other of two remaining cylinders, there is a steam chamber in each piston and a port in its side; steam is supplied from the boiler by means of a hollow rod passing through the top of the cylinder into a steam chest; when the piston has reached about three-fourths of its downward stroke the steam port in it overlaps a port formed in the side of its cylinder, and steam then passes to the top of another of the cylinders; when, on the other hand, the piston has reached about one-half its return stroke, it uncovers the port in the side of its cylinder, and allows the steam to escape from the cylinder into which it was previously admitted, into a casing round the crank shaft; from which the exhaust steam is taken either to a condenser or to the air. Where it is desired to reverse the engine; the ports to the top of each cylinder and those to the sides of each cylinder meet in a three-way cock; and this cock, by connecting the port in the side of any one cylinder, with that to the top of either of the other cylinders, reverses the engine. It will be seen that the wear upon the connecting rods and crank shaft bearings is always in one direction, namely, downwards; so that no moderate amount of wear affects the working of the engine, and the whole machine is

perfectly noiseless. The tubes through the tops of the cylinders, besides forming guides for the pistons, allow a great number of revolutions to be made without any loss of power in stopping and setting in motion again, the amount of dead weight in motion being small; and the pressure upon the three tubes keeps them in equilibrium, but still maintains a constant pressure upon all the bearings. All the lubrication is done through a steam lubricator on the steam chest, and whatever oil is wasted in the cylinders passes down to the bottom of the casing, and lubricates the lower ends of the connecting rods as they pass round. The upper ends of the connecting rods receive their lubrication direct from the steam chamber in the piston, by way of small holes drilled through the bottom of the chamber. As the stroke of the engine is so large in proportion to the width of the steam ports, the latter are opened and closed very quickly, and there is little or no back pressure in the cylinders. By some slight modifications the engine may be made compound, and the crank shaft may, if necessary, be kept outside. When there is a casing round the shaft, the feed-water may be heated by being pumped through pipes passing through that casing.

The very high piston speed at which these engines can be run, reduces the loss from condensation, and makes a high grade of expansion possible. Where necessary a speed of 800 to 1,000 revolutions per minute can be attained, and maintained for a length of time without thumping or adjustment of bearings; while the regularity of the motion makes it possible to run quite slowly without any need for a fly-wheel. There is no dead centre, and the engine can be reversed instantaneously and with certainty at either high or low speeds.

As will be seen the shape of the engines is particularly suitable for small marine work; the shaft can be kept low in a boat of the finest lines, and where it is advisable to give the steersman perfect control over the boat, the engine can be placed in the stern, so that he can have one hand on the tiller and the other on the starting lever, thus saving the trouble and delay of communicating with the engineer, either by word of mouth or signal. Where it is not convenient or advisable to place the engine in the stern, the extreme simplicity of the reversing gear makes it an easy matter to lead a rod and lever from the engine to the steering wheel, wherever it happens to be placed, and thus to attain the same object, viz.; that of placing the entire control of the boat in the hands of one man. This is of the utmost importance on rivers where, as on the Thames, a launch has frequently to make its way through a perfect crowd of small boats. The arrangement has also been adopted in the case of torpedo launches, and the advantages of the plan, for these boats; where every second may be of the greatest importance, are obvious.

It will be noticed that the reversing of the engine being effected by a three-way valve, which has no connection with any of the working parts; the reversing handle does not need jamming or holding in position, but remains where it is set. It has been proved by actual experiment that the frictional resistance in these engines is exceedingly small; the actual

horse-power as measured by the dynamometer brake being from 90 per cent. to 95 per cent. of the power shown on the indicator diagram.

List of sizes, power and weight, of the "Willans" engines :—

Diameter of Cylinders	3½ in.	4 in.	4½ in.	5 in.	5½ in.	6 in.	6½ in.	7 in.	8 in.	10 in.
Length of Stroke	4 in.	5 in.	5 in.	6 in.	7 in.	8 in.	8 in.	9 in.	10 in.	12 in.
No. of Revolutions per Minute.	500	500	500	450	450	400	400	400	350	300
Indicated HP. at 85 lbs. boiler pressure and the above No. of Revolutions ..	9	15	19	25	32	42	50	60	80	130
Weight of Engine	1½ cwt	2½ cwt	3 cwt	3½ cwt	5½ cwt.	6½ cwt	7 cwt	8½ cwt	13 cwt	25 cwt
Extreme Length of Engine Bed	14 in.	15 in.	17 in.	18½ in.	21 in.	23 in.	23 in.	26 in.	30 in.	37½ in.
Extreme Width of ditto ..	12½ in.	16 in.	17½ in.	18 in.	18½ in.	24 in.	24 in.	24 in.	26 in.	30 in.

These engines have been supplied in sizes varying from 5 H.P. to 200 H.P. indicated, for use in the English, German, Portuguese, Dutch, Swedish, Turkish, Brazilian, Chilian and Japanese navies ; and in addition to a large number of yacht and launch owners.

BOILERS.—(THE DIFFERENT CLASSES OF.)

Boilers may be classed under four distinctive types. The Cylindrical Return Tube Boiler with one or two furnaces ; in general use for yachts and the larger description of craft. The Locomotive Boiler; for the larger class of steam launches. The Vertical or Upright Boiler; for small launches. And different varieties of the Water Tube type for torpedo boats, &c. For boilers with less than 60 feet of heating surface the cylindrical return tube boiler is heavy and difficult to make; for smaller sizes the horizontal tubular boiler is sometimes preferable; or where lightness is of the utmost importance the locomotive or approved examples of the vertical boiler. The vertical boiler has the advantage of occupying least room, but unless well designed it is unsightly, high, and raises the centre of gravity. The locomotive and horizontal boilers take up considerable room lengthwise, but have the advantage of lying well down, and are extremely light. The water tube boiler is of great advantage in raising steam quickly and maintaining high pressures, with economy of fuel, such as may be required in the service of torpedo boats. But where comfort is the main object, and a strict watchful responsibility not entailed to provide against running short of water, one or other of the three previous classes is to be preferred. Theoretically the water tube boiler is the most perfect, strongest, and most economical boiler extant. The Perkins boiler, for instance, has been worked at 500 lbs. pressure, and tubes on that principle is stated to have been in use for 40 years.

The Cylindrical Boiler.—(Proportions.)—The woodcut on page 4 shows a view of the ordinary cylindrical return tube marine boiler, as used for yachts and launches. This particular cut, with the following table of proportions in regard to nominal horse power and heating surface, is supplied us by Messrs. Abbott & Co., Newark-on-Trent, whom we believe few firms have more experience or turn out a greater number of the small class of cylindrical boilers for yachts, &c.

Nom. H.P	Dia.	Length.	Dia. of Flue.	No. & Dia. of Tubes.	Dome.	Heating Surface.	Approx. Wt. Cwt.
6	4·6	6·0	2·3	32 × 2¼	1·9 × 2·0	112	45
8	4·6	6·6	2·3	34 × 2½	1·9 × 2·0	138	50
10	4·9	7·6	2·4	40 × 2½	1·9 × 2·0	160	60
12	5·0	7·0	2·6	44 × 2½	1·9 × 2·3	180	65
15	5·6	7·6	2·9	50 × 2½	1·9 × 2·3	230	75
18	6·0	7·6	2·10	58 × 2½	2·0 × 2·3	300	85
20	6·3	8·0	3·0	63 × 2½	2·3 × 2·3	340	104
25	6·6	8·0	3·2	80 × 2½	2·3 × 2·3	356	110
30	7·3	9·0	Two flues. 2·3	86 × 2¾	2·6 × 2·6	540	150
40	8·0	9·6	2·4	102 × 2¾	2·6 × 2·6	614	170

Inspection of New Boilers.—It is very essential that attention should be drawn to the vital importance of the boiler being large enough in all yachts and launches, otherwise directly the heating surfaces get scaled over, the owner has the unpleasant experience of his boat running several miles an hour less than when new, and with everlasting stoking and smoke; also owners cannot possibly inspect their boilers, and should consequently demand that they be made by firms, whose reputation will not allow them to turn out bad work; and such makers much prefer making boilers under the inspection of either Lloyd's or the Board of Trade Surveyors, or other responsible inspectors, this is of course expensive still it is a wise precaution, and a little extra cost in this way is well spent, as a yacht becomes totally incapable, if the boiler gives out. The boiler, we again endeavour to make plain, is the most vital part of the vessel; a fact which engineers in general and owners are apt to forget; too much

importance cannot be attached to the matter, when being supplied with a new boat, or when the boiler is being replaced in an old one. Every attention should be given to both the design and the workmanship of the boiler, and any extra expense will amply repay itself in the end, if the boiler while under construction be placed in the hands of a responsible inspector. It may safely be said, that there are, only about one out of five hundred amongst engineers generally, whether engaged in the constructive design of engines or otherwise, who are thoroughly and efficiently posted in the various strains and necessities regarding boilers, and it cannot be expected that the non-professional owner is likely to be a competent judge in this matter, therefore the necessity of proper and critical inspection.

The Design of Boilers.—To design a marine boiler seems at first sight a very simple affair. But if all the particular duties and requirements of an efficient boiler be carefully and thoughtfully considered, it will be seen that there are numerous difficulties and necessities involved which make it an arduous task, when the ordinary type of boiler is in question, and a maximum of efficiency required. Among the data to be taken into account are the following. Efficient evaporative qualities, economy of coal consumpt, strength to resist pressure, strains due to expansion, proportionate riveting, equable heating surface, grate surface, and the cubical capacity of furnaces for the proper combustion of the fuel and gases, uniform circulation, the prevention of priming, accessibility in all parts for examination and cleaning purposes, facility of construction, cost of manufacture, marketable size of plates, and space occupied in the ship, etc., etc.

The great fault of most boilers is that they are too small for the work required; causing a waste of fuel, and very often troublesome priming. The size or capacity of the furnace and combustion chamber is seldom large enough, which is the chief secret of an economical boiler.

A great deal might be said upon the subject of boiler design, but as it here might be out of place we confine ourselves to a few remarks on the circular boiler. If a slice could be taken off the bottom underneath the flue, which part is worse than useless for evaporative purposes, also a slice from off each of the sides, we would have a better steaming boiler and a boiler of less weight, but as it would leave a square or rectangular form, it would be incompatible with the strength required for high pressures. Also if the depth of the furnace could be increased to about twice the usual diameter, we would burn less coal and have more efficient heating surface but as before the form necessary to suit this class of boiler would be incompatible with strength.

The tubes should be placed in rows vertically and horizontally, for the double purpose of facility in cleaning or scaling, and to offer as little obstruction as possible to the ascending currents and globules of steam. The height of the top row of tubes, which is of considerable importance, should be as near the centre line of boiler as the number of tubes and the size of the boiler will permit—the height of the top row of tubes in

practice is usually at two-thirds the diameter of the boiler. The superficial surface of the water is greatest at this point, and the higher the water-level is raised the less its area becomes, according to the decreasing curvature of the plates; and the more the evaporation of steam is reduced: while it increases the violent ebullition and liability to prime. The curvature of the plates has a tendency to throw the circulating currents of water rising at the sides in a central direction where the two opposite currents meet, causing violent commotion, which leads to quantities of water being carried off with the steam. This is sometimes partially prevented by placing wash or baffle plates longitudinally across the steam space of boilers.

Numerous authorities could be quoted all tending to prove what are the requisite qualities of a good boiler. In the first place, to ensure a proper mixing of the gases and a thorough combustion of the fuel, a boiler must have a large fire box or combustion chamber, so that the gases may be completely ignited before coming in close contact, to be cooled, by the plates of the boiler. In the ordinary marine boiler, with small contracted flues, thorough combustion can never take place, the greater part of the gaseous products passing off, after being partially cooled, in the form of smoke. Secondly, the amount of water contained must bear a certain proportion to the quantity of steam to be raised—the less water, the faster steam can be had—but, to be consistent with safety and a steady practical generation of steam, a limit must be fixed. In the present cylindrical marine boiler a mass of water is carried which is worse than useless, as it hinders evaporation in proportion to its weight and bulk. The water tube boiler, in this particular, has everything in its favour. Each separate tube being a boiler in itself, and the tubes being of small diameter, are of great strength, although of very thin material, and offering a very trifling medium interposing between the water and flame. Most water tube boilers have their tubes too long in proportion to their diameter, with the consequent result that steam is generated faster than water can be supplied, resulting in the bareing and burning of the tubes, and in some cases, explosion.

The circulation, to be good, must be natural and free—no bends or tortuous passages ; ample steam space provided, and sufficient surface of water. An insufficient surface retards the evaporation materially. The tubes should not be too long, and should be easy of access for cleaning, examination, or removal when required. The boiler should be light in weight, and as small as possible, to save valuable space in the vessel ; simple in construction, portable and easily put together in the manufacture. In all these details the water tube boiler has the advantage. It is lighter, less bulky, a better steam generator, a more economical consumer of fuel, a safer boiler, and costs less than the present antiquated and cumbrous marine boiler, and most of previous disastrous failures with water tube boilers can easily be explained away, simply because nearly all that has been taught on the matter since the introduction of steam has been ignored, and the natural laws of heat and water been overlooked and neglected.

Vertical Launch Boilers.—Generally speaking the vertical boiler has been a steam generator, not always to be commended, and in common with all boilers the united ability of a legion of inventors has not produced one on all points free from objection. Two types may commonly be noticed. In one the flame and gases pass through vertical tubes into the funnel; here the heating surfaces are vertical, and therefore the very worst for the generation of steam; further, about half the length of the fire tubes are in the steam space, and out of the water, and thus get rapidly burnt and destroyed. In the other variety, which may be called the cross water tube boiler, the flame and gases play round cross tubes through which the water passes, and thence into the funnel, which is in the steam space. Perhaps this is a more defective form than the other, for the extravagant waste of heat is indicated by the base of the funnel being frequently red hot. There is, besides, a risk of priming, for the steam generated in the cross tubes when of a flat or oval form has difficulty in escaping, and the circulation is not perfect. The total result is that the boiler, while being wasteful, is rendered troublesome by a constant tendency of the fire-box to become bulged, and the vertical fire tubes (or funnel in some cases) to collapse.

Strains in the Small Vertical Boiler.—In the common class of small vertical boilers, with the smoke-pipe or uptake passing up through the steam space, there is such a complication or diversity of strains involved, owing to the peculiar and irregular form of construction, that causes the subject to be a very difficult one to deal with, or, at least, to be certain of without a careful study and a series of experiments.

However, it may be shown what is considered to be the most prominent strains affecting the safety of this boiler. The danger sometimes ascribed to this class of boiler through the sudden accumulation of steam upon a stoppage of work, no doubt must exist, more or less, but that is not usually the entire cause of their failure when they give way. On the other hand, it is often asserted that their strength is sufficient to resist any ordinary pressure which they may be subject to, and that accidents seldom occur except when the boiler is worn out.

The principal reason for their usual sufficiency and favour lies in their great rigidity, due to their small diameter and excessive strength of plate; but these plates are in certain places subject to great variation of temperature by exposure to the flame and without protection from the water, and it must be in any case decidedly bad, where the heated gases are allowed to play upon the plates of the steam space of the boiler above the water level; for several reasons:—First, the plates are liable to become red hot, thereby reducing their strength enormously. In one case, that of a Board of Trade inquiry some time ago, concerning the explosion of a superheater, it was stated that the plates were constantly liable to become red hot; and, at the working pressure, the superheater was on the point of explosion whenever the plates became so. The relative strengths of the plates when tested hot and cold was as 1 to 5·32, and the experiments

proved conclusively that all structures of the kind subject to the impact of flame are dangerous. However, this danger is to a certain extent counteracted in the small vertical boiler by the small diameter of the uptake flue or pipe. Secondly, those parts devoid of water becoming overheated from the action of the flame on the outside, the steam naturally undergoes decomposition on the inside, and starts a most active corrosion on the plates. For instance, at the line of the water level—in contact with the uptake tube above mentioned—the corroding or pitting will be most apparent. The constantly varying water level, due to increase and release of pressure, and the violent ebullition of the boiling water, is continually wetting and cooling, while the fire is heating and drying the plate at this line or circle round the tube, causing a consequent decomposition of steam, which, freeing the oxygen, and uniting with the iron, forms oxide of iron, attacking the soft iron between the fibres; and pitting and holeing at those stops where the splashing and spluttering of the water come in contact with the plates, is the result. The oxide of iron or rust so formed is again washed off, offering a cleaner surface to be again attacked, and by continual repetition the plates in the course of time become worn or eaten through. The third defect, and the most difficult to deal with, is the strains due to the difference of expansion in the different geometrical forms composing the boiler. The outside cylinder or shell being exposed to the atmosphere on one side, the expansion in that part may be considered *nil*, or, at least, only so much as may be due to the temperature of the steam. Increased expansion of the plates is most to be expected in the heated uptake tube, and the conical fire-box or furnace—especially in the former—an upward thrust tending to lift the crown plate is resisted, and prevented, except in a very small degree, by the stiff rigidity of the semicircular cambered plate, and it is possible that it might be an advantage to have the top plate perfectly flat in place of the usual flanged camber form of the plate, thereby allowing a certain amount of elasticity or freedom to rise and fall with the expanding vertical tube. These tubes are sometimes made conical, with the small end of the cone downwards, with the object of allowing the heated gases impinging against the plate as little as possible. There is also a double advantage gained, as by this means the bottom flange is allowed of being admitted through the hole cut in the crown. If any elongation of the tube takes place, which there must be, and the top of the boiler remains a rigid fixture, all the thrust must be in a downward direction towards the furnace, the crown of which also, like the crown of the boiler, owing to the cambered nature of its construction, is perfectly rigid; therefore, the thrust comes upon the walls of the conical furnace. Whatever expansion there may be in the fire-box (and it is but reasonable to suppose that there is a certain amount more or less), is resisted in a vertical direction downwards by the stiffness of the ring joining the inner and outer shells at the bottom, which is comparatively cool, being under the fire grate; consequently all the expansion, elongation, or thrust is in an upward direction, which, meeting the downward thrust from the uptake, culminates in tending to buckle the inner shell plate

at its weakest or least stayed part, which part is immediately opposite the fire-door.

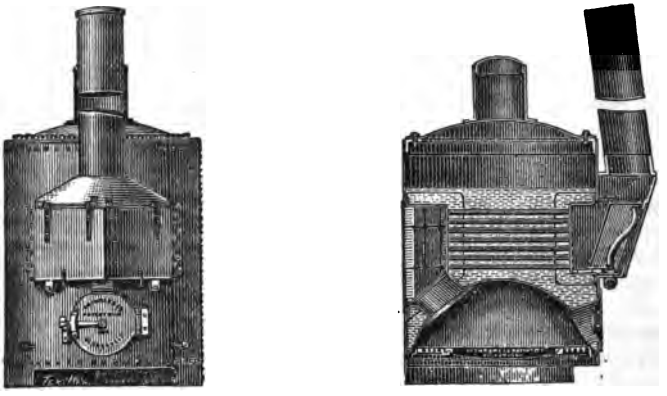
The cross tubes in the upper part form strong and efficient stays, preventing any likelihood of collapse in that direction. The fire-door opening forms another strong stay for the central part of the furnace, but on one side only, while the opposite side on the same line has no stay whatever. Also a current of air, when the fire door is opened, rushes against this spot with greater force than at any other, increasing the tendency to weaken the plate by extra heating. Again, any expansion of the fire-box, in the direction of its diameter, is obstructed everywhere by the cross tubes and the fire-door opening, except at this one place, which naturally yields to the steam in favour of the rigidity of the other side, and the circle of the furnace at this line takes in consequence an oval form with a flat side. In fact, all, or nearly all, the various forces created by heating and pressure, exert themselves on this devoted spot, terminating sooner or later, as the boiler may be forced, in the buckling, cracking, and final collapse and rending of the plate, with more or less disastrous results.

According to the natural laws of expansion, it is known that wrought iron expands one ten-thousandth part of its length by an increase of 16° F. of temperature, or equivalent to a force exerted of one ton per square inch. Suppose at any time the uptake tube be heated to 700° (iron at 750° appears cherry red in the dark), and that the temperature of the crown and outer shell be equal to that of the steam, say at 60 lb., which equivalent temperature would be about 300°, the expansion due to the difference of these temperatures would exert a force downwards on the inner shell of 12½ tons per square inch, not to say anything of the increased temperature and force exerted by the inner shell itself, which is impossible to ascertain. The pressure of steam would also exert a force of about 2,000 lb. against the side of the furnace—which means that there would be a crushing or buckling thrust of 12½ tons upon every square inch of plate section of the inner shell, while a force of nearly one ton is ready to take advantage of any weakness, crack, or flaw, that may accrue therefrom.

These ideas have been borne out by experience, the writer having known several cases where these boilers gave way at this exact spot. In one instance the boiler, a small one, went up perpendicular like a rocket, at least a hundred feet high. Any slight buckling or flattening of plate should be carefully looked after, especially in old and second-hand boilers that have been lying idle for some time, and which generally have not had the best of usage, if their age and antecedents are unknown. A collapse of the furnace does not as a rule give a very long warning, but there is usually some slight indication of weakness, giving due notice if carefully watched. The giving out of the uptake tube is not so flighty or so disastrous in its results, as the pitting being gradual; an occasional inspection will always allow of the thickness and state of the plate being known.

Cochrane's Boiler.—The illustrations on page 64 represent a front view and section of a neat and compact launch boiler, which is free from

most of the usual defects of vertical boilers. It is of the horizontal fire-tube system, with a dome fire-box crown, the plates of which are welded solid; the products of combustion pass from the fire into the combustion chamber on the left hand, thence through the tubes into the funnel, and by the time they reach the latter, the available heat is all abstracted from them, so perfectly, indeed, that the paint on the funnel of a boiler, tried, which had been some weeks at work, was not injured. The inside of the door of the combustion chamber is lined with fire brick, and in the smaller boilers it is usual to supply fuel through this door and through the opening shown on the left-hand side in the furnace crown, thus dispensing with the door on the right. The boiler is of strong design, and it is difficult to see where failure can occur. The tube plates are suitably flanged for attachment at once to the shell, and they are stayed by the tubes. No part of the heating surface is above the water line, yet there is ample steam space, although the boiler stands lower than other vertical boilers for the same power. The heating surface allowed is about 10 square feet per horse power, and we are informed that it has often evaporated over 10 lbs. of water per lb. of coal—a very creditable performance, when the best a Lancashire boiler can do is about 9 lbs. The boiler has these further advantages, it is thoroughly accessible, every part of it can be examined, there is not a rivet in the whole boiler which cannot be renewed if necessary. Tubes, tube plates, and furnace can be easily and thoroughly cleaned and scaled, and the tubes can be swept with the utmost ease. If a tube should burst it can be plugged at both ends without even blowing off steam or drawing the fire, and any or all tubes can be replaced without the slightest difficulty. The boiler is patented by Messrs. Cochrane & Co., of Birkenhead, and has been fitted by them into several boats, including the model, of the Emperor of Russia's yacht the "*Livadia.*"



COCHRANE'S PATENT BOILER AS ADAPTED FOR STEAM LAUNCHES.

To enable these boilers to be properly cleaned, the top of the boiler in the small sizes is bolted on, so that perfect access to the interior is afforded. The advantage thus given to those who are compelled to use salt or muddy water will be readily appreciated. These boilers have been proved to be most satisfactory generators of steam, and are very easily managed. The space saved in a small boat, by the use of a boiler of this type, is sufficiently obvious; also the centre of gravity is kept very low so as not to render the boat crank.

The following is a table of dimensions of the heating surface and weights.

Class.	Height at side including Ashpit.		Diam.		Heating Surface.	Tubes.		Grate Area.	Approximate Weight.
						No.	Diam.		
	ft.	in.	ft.	in.	sq. ft.		in.	sq. ft.	cwt.
"Gnat".....	2	3	1	6	10	26	$1\frac{1}{8}$	$1\frac{1}{4}$	$3\frac{1}{2}$
"Gadfly"	2	6	1	9	15	38	$1\frac{1}{8}$	$1\frac{3}{4}$	5
"Ladybird" ...	2	9	2	0	20	42	$1\frac{1}{8}$	$2\frac{1}{4}$	6
"Mayfly"	3	0	2	6	30	45	$1\frac{1}{8}$	$3\frac{1}{2}$	8
"Blackbeetle".	3	6	2	9	40	50	$1\frac{1}{4}$	$4\frac{3}{4}$	12
"Dragonfly"...	4	0	3	0	60	72	$1\frac{1}{4}$	6	16
"Hornet"	4	6	3	6	90	99	$1\frac{1}{4}$	8	22
"Butterfly" ...	5	3	4	3	120	97	$1\frac{1}{3}$	11	28
"Spider"	6	3	5	0	150	94	$1\frac{1}{2}$	15	36

The fittings of the boilers as given above, include funnel, smoke-box combustion-chamber, plate and lining, fire-door, manhole and cover, and mudhole and door. Mountings consist of water-gauge, 2 test-cocks, spring safety-valve, stop-valve, check-valve, pressure-gauge, steam-jet pipe and cock, scum-cock, blow-off cock, and blast-pipe. All plates exposed to the action of the fire are "Bowling," or equal quality; or steel.

The boilers are tested to at least 150 lbs. per square inch and tried by steam before leaving the works; and are guaranteed to pass survey by the Board of Trade, or Lloyds.

Jones' Vertical Boiler.—This boiler is on a par with the former, for extreme simplicity and compactness of design, having at the same time great strength of form.

The design which is of the vertical water tube system, is almost theoreticaly perfect—if such a thing could be—and in practice its utility is not far short of theory. The fire-box has a dome crown, like the Cochrane boiler, but instead of horizontal fire tubes, a series of vertical water tubes pass upwards through the combustion chamber; while the heated gases and smoke passes out at the side of the shell below the water level, the heated water rises upwards through the central tubes, and larger tubes are

arranged round the outside of the combustion chamber, to again return the water to the lower parts of the boiler, thus ensuring a well designed and complete circulation. The hot gases and flame coming into direct contact with the outside of the vertical tubes, whilst the return tubes being placed outside the influence of the flame ensures the most rapid circulation and precludes all possibility of scaling, hence its especial adaptability to marine purposes. Every part is readily accessable for cleaning and examination. The disposition and extent of heating surface—which is very large—renders it useful for raising steam quickly and provides an abundant supply with economy. The usual fittings are applicable to this boiler, which is also capable of standing high pressure hydraulic and steam tests usual with the class.

The Blake and Tangye Boilers,—Are also of the vertical water-tube class, of somewhat similar principal to the Jones' Boiler, but of different arrangement of design and method of detail.

The Messenger Boiler.—Is also a launch boiler which has many favorable properties, such as lightness, compactness, and quick steaming powers, and is easily overhauled and cleaned when of small size.

There are many other small vertical boilers, which might be more or less favorably mentioned, but the foregoing particulars will be sufficient as a guide to the peculiarities of the vertical boiler in general.

The Locomotive Boiler.—When flame and heated gases pass through tubes surrounded by water, the heating surface is most efficient when the tubes are horizontal, and furthermore the gases will have done practically their full duty before they have passed two feet through those tubes. For instance, in the locomotive and portable engine boiler it is well known that the vast portion of the work is done in the tubes, for the first 15 to 18 inches from the furnace tube plate, still the large cubic contents of the combustion chamber, and a limited body of water in proportion to the power of the boiler, makes the locomotive form one of the most efficient boilers that we have for steam launch purposes, more especially when the large grate surface and furnace is augmented by the forced blast. In the locomotive furnace we have a consumption of fuel four to six times that of the ordinary furnace with perfect safety.

Messrs. Halsey & Co., fit their fast boats with a boiler of the locomotive type, which is capable of being worked up to 120 lbs. per square inch, in which steam can be raised in half-an-hour, but in order to provide for every emergency, such as might occur in torpedo boats, and auxiliary boiler is provided, in which steam at 120 lbs. pressure can be got in seven minutes. This auxiliary boiler is very light, and consists entirely of heating surface.

The Water Tube Boiler.—It is well known that one of the most important questions relating to steamship propulsion and the economic working of steam vessels, hinges itself, to a very great extent, upon

the improvement of the marine boiler. The existing type of marine boiler is quite in the rear of the modern compound engine, simply owing to the fact that, while ample attention has been given to the engine and the theory of expansion, the boiler, or the fundamental root of the whole economy, has been ignored, being hitherto neglected by constructive engineers in general, on the supposition that anything would do for a boiler, and that the designing of such could safely be left to anyone who could put the plates together. However, it is not so, as the present every day requirements are beginning to show. The engineering profession are at last becoming keenly alive to all this, and the result has been, of late, a series of designs for various kinds of boilers, including a few of the water tube type; which type, if perfectly designed, would have everything in its favour, and would quickly supersede all others in the questions of economy, lightness, and strength. These latter designs have been all more or less efficient, but also in many respects totally deficient. But at the same time the experience thus gained has been all pointing in the direction of needful requirements and consequent improvements. Each successive patent in water tube boilers superseding its predecessors in value as to its general efficiency.

One great drawback to the introduction of new boilers is the fact that the shipowning public, through want of the requisite knowledge of the matter, have been and are still afraid to meddle with such a supposed dangerous subject, and so will rather go on in the old groove of using an old though known type of boiler than risk introducing a novelty of which at least they have a very faint notion, regarding its trustworthiness and safety. This has unfortunately been accelerated by a few disastrous attempts, of some of the pioneers in this direction.

The water tube boiler, in various phases, has been before the public for somewhere about ten years, and during that time, though very little advancement has been made in introducing it into steamships, the time thus apparently lost will eventually be of great value to the successful boiler that may be designed to suit the public point of faith, which all this time and labour expended has been tending to educate them up to, and the competition ensured by the first to take it up will eventually lead to such a boiler becoming general, and the present cumbrous weighty fuel waster become a thing of the past.

Donaldson's Boiler.—Is a boiler of the water tube class to which most of the foregoing principles laid down apply in a direct manner. This particular modification was designed expressly for use in steam launches, torpedo boats, &c., but is also equally applicable to steam vessels of any size.

In explanation, the boiler consists of a cylindrical shell, having attached at each end large eccentric boxes, projecting downwards and forming the water boxes to which are fixed the water tubes which pass right through longitudinally in the direction of the boiler's length. These tubes are in one piece, and are fitted into the plates with conical nuts in such a manner that the greater the pressure, the tighter they will become. The ends of

the tubes are closed with screwed gas pipe caps, admitting of easy facility for cleaning and examination. The parts of the tubes that pass through the water boxes are perforated with 2-inch holes for the steam and water to pass through. A piece is cut out of the cylindrical shell of the boiler at the back of the fire-box, on the underside, forming the combustion chamber, from which ordinary fire tubes are carried to the front plate of the boiler. The boiler is thus a combination of the water tube and fire tube systems. The whole is supported and carried on iron framework, which is built up and lined with fire brick, allowing of a large capacity of fire box.

It is claimed that the advantages of this boiler, are, that it affords great strength, allows for expansion, occupies smaller space, is much more efficient as a steam raiser, is more economical in coal (as the large furnace affords free space for complete combustion), is perfectly safe, the circulation is certain, is easily overhauled or cleaned, is of less weight than the ordinary marine boiler, and being a combination or a medium between theory and practice, is more likely to gain faith with steam users and shipowners.

It has the advantages of the present marine boiler, the present water tube boiler, and the locomotive furnace, without the weight and waste of the former or the uncertainty of the water tube boiler, while the arrangement enables a very large heating surface to be obtained. It has been admitted that the heating surface of a water tube is about six times more value than an ordinary fire tube, still, without taking this into account, the heating surface in relation to the size of the boiler is enormous, being about double that of the class generally in use for small craft, and by simply increasing the diameter of the end boxes, the number of tubes and heating surface can be increased in a manner speaking, indefinitely.

Messrs. Yarrow & Co., have introduced into their steam launches and torpedo boats, a new design of boiler. It is a tubulous boiler, and consists first of a couple of vertical wrought-iron tubes about 4 feet high and 6 inches in diameter and placed outside the furnace. The furnace casing is 4 feet high by 3 feet square in plan. Into one of the vertical tubes fifteen horizontal tubes 1 inch in diameter are tapped and are carried thence into the furnace. Here each tube passes backwards and forwards eight times, the bars formed by the tubes breaking line, so that the heat passes freely around all. The end of each tube is passed out through the furnace casing, and is tapped into the second large vertical tube or receiver. The first receiver contains water which a feed and a circulating pump deliver into it. This water is forced through the fifteen sets of independent horizontal tubes and issues into the second receiver in the shape of water and steam. The steam is taken off at the top to the engines, whilst the water falls to the bottom, where the circulating pump takes its suction, so that whilst the engine is at work a complete and rapid circulation of water takes place through the boiler. Safety is ensured by a far greater proportion of water being supplied to the tubes than can be raised into steam. This boiler has the advantage of being practically safe, inasmuch as in the event of any section giving way it can

be quickly isolated from the rest, and the working of the boiler continued. It has the further advantage of occupying a very small space as compared with its power; of being economical in first cost, and of having all its parts accessible for repairs. Steam is raised in it very rapidly, as evidenced on a trial when 80 lb. steam was obtained in seven minutes from the time of lighting the fire. That time would have been increased by a couple of minutes or so had the boiler been quite cold at starting, which it was not, but slightly warm.

Amongst this class of boiler involving the same principles, may be named the Perkins, the Herreshoff, the Watts, the Roots, and the Howard Boilers, also several others, all more or less differing in the mode of fixing the tubes and the design of details.

INJECTORS.

In most Launches and small craft, injectors are now much used in place of feed pumps, to supply the boiler. On some accounts the injector is more reliable than the pump, as there are no valves or moveable parts to break or get out of order, besides occupying much less space it will work under all the conditions where a pump would be used. One important advantage of the injector over a pump is, that all the steam required to operate it, is condensed in the water, thereby heating it, and returning it all into the boiler, and enabling hot water to be fed into the boiler without the use of a feed heater. The injector requires no oiling, while a pump requires attention and lubrication, also the exhaust steam is generally wasted; the only loss of steam by using the injector is by radiation from the pipes, and occurs in no greater measure with the injector than with the pumps.

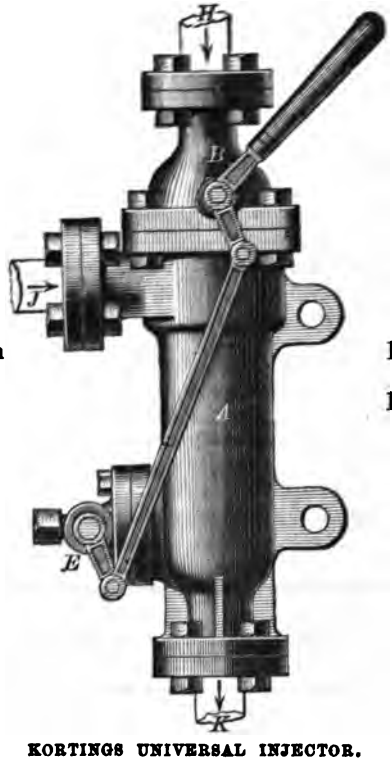
There are now a great number and variety of injectors used, since the original one was introduced by Giffard, the result of a chance experiment for another purpose. Of those fitted to yachts, launches, and torpedo boats, it will be sufficient for the purpose to mention two, with information and instructions common to both and the class in general, viz., Korting's Universal Injector, and the Hancock Inspirator.

The Universal Injector.—Works with hot or cold water, and with high or low steam-pressure, without requiring any regulation of the steam or water. It is a combination of two complete injectors; the first or lifting injector delivering the water into the second or feeding injector, and as the first completely regulates the water supply of the second, as required for varying steam pressures, no special water adjustment is necessary; by this combination the advantages are obtained of requiring no regulation, and cannot be improperly handled in starting. It has no moving or wearing parts, and there being no overflow, it cannot loose any water when working. It works with a maximum temperature of feed-water of 150 degrees Fahrenheit. In lifting, it will work with any steam-pressure between 12 lbs. and 150 lbs.; with steam of 30 lbs. to 75 lbs. pressure the

temperature of the feed-water may be as high as 140 degrees Fahrenheit when lifting or sucking the water less than 7 feet; and will lift cold water 20 feet high. As fitted in launches they have been kept feeding at intervals with all pressures from 80 lbs. to 5 lbs. when blowing down, and by simply moving the lever right or left, without missing their feed.

H.—Steam branch

J.—Suction.



K.—Delivery.

E.—Starting cock.

KORTINGS UNIVERSAL INJECTOR.

The steam is taken by a pipe from some part of the boiler as high as possible, to prevent the water from the boiler getting into the pipe when rolling or priming, and is lead to the top of the injector, the suction pipe is attached to the side, and the delivery pipe to the bottom, while a small starting cock is placed at the side lower down than the suction branch, a lever is connected to the steam and starting cocks by a coupling rod, so that when the lever is moved, both of the cocks open simultaneously. In fixing the injector all pipes should be thoroughly cleared out by blowing steam through them before connecting them, and the suction pipe must be perfectly air tight. If the steam pipe is a long one, it is better to have it lagged. A large but fine mesh seive must be fitted into the water supply

tank, etc., on the end of the suction pipe, to prevent any dirt or grit from getting into the nozzles of the injector.

To put on the feed: the lever is turned slightly until the starting cock is opened and water issues from it, then the lever is continued to be turned slowly in the same direction, until the starting cock is entirely closed. To shut off the feed: reverse the lever to its original position. Should steam at any time blow back through the water pipe, let some water flow through the pipe and the injector before starting again, in order to cool both to their ordinary temperature.

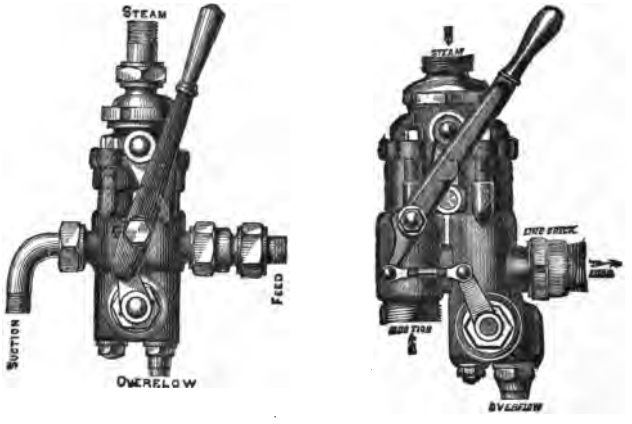
When taking the injector to pieces, care must be taken not to injure the nozzles, and to replace them in their proper seats.

Appended is a table of the sizes made of Korting's Universal Injector, with the number of gallons they will deliver per hour at 60 lbs. pressure, and the bore of the steam and water pipes necessary for these sizes. If the figures in the column of gallons supplied per hour be divided by 10, that is to cut off one figure to the right, the remaining figures will give approximately the nominal horse power of boiler, the injector is suitable for, thus No. 5 is equivalent to a 26 nominal horse power boiler; the N.H.P. being taken as is customary upon the assumption that a cubic foot of water evaporated into steam is equivalent to 1 horse power. At the same time a No. 5 would be sufficient for an indicated horse power of nearly 3 times the nominal or about 70 I.H.P.

No. of Injector.	Gallons of Water delivered per hour at 60 lb. steam-pressure.	Bore of Steam and Water Pipes. Inches.
3	92	$\frac{3}{4}$
4	164	1
5	260	$1\frac{1}{4}$
6	370	$1\frac{1}{4}$
7	510	$1\frac{1}{2}$
8	660	$1\frac{1}{2}$
9	830	$1\frac{3}{4}$
10	1040	$1\frac{3}{4}$
11	1250	2
12	1490	2

The Hancock Inspirator.—The inspirator is a double apparatus, one-half of which is a lifter, and the other half a forcer; the lifter drawing the water and delivering it to the forcer, which delivers it to the boiler at any steam pressure; without adjustment. The operations of starting and stopping are performed by the movement of a single lever, and the instrument is self contained, being ready for attachment without the use of additional valves. A slight movement of the starting-lever admits steam to the lifting jet; when water issues from the overflow, a further movement of the starting-lever closes one of the valves, thus turning the supply water through the force nozzle, admits steam to the forcing jet, and closes the waste valve; thus starting the instrument.

The essential conditions of its successful operation are, First, a tight suction; the inspirator raises the water by causing a vacuum, and of course this cannot be obtained without having the suction pipe and connections absolutely air-tight. Secondly, steam must be taken direct from the boiler; the boiler should be tapped so as to secure dry steam. The connection should not be made with other steam pipe for a number of reasons. Where steam pipes are already connected with the boiler it is for



THE HANCOCK INSPIRATOR.

some purpose, and they are not likely to be of sufficient capacity to supply the inspirator and do the work for which they were originally designed; also the connection should not be with the main steam pipe however large, as the pressure will be so irregular and intermittent as to seriously interfere with the successful working of the inspirator. Therefore the boiler should be tapped where the dryest steam can be obtained; but if it be obliged to connect with the steam pipe, tap it on the upper side so as to avoid the drip caused by the condensation in the large pipe, otherwise it will be little else than a drain to draw off the condensed water from the large pipe.

If the steam pipe is full of hot water when it is wished to start the inspirator, open the steam valve sufficiently to allow the water to pass off through the instrument and out at the overflow.

If the suction pipe is filled with hot water, there are two ways to get rid of it; one, is the common way of cooling the inspirator and suction with cold water, and the other and best way is by pumping the water out, by letting the steam on and off suddenly at the starting valve until the hot water is all disposed of.

If the inspirator does not lift water well, in almost every case the difficulty will be found with the suction, which must be absolutely tight to secure good results; see also that the overflow is wide open and not choked by having the pipe attachments too small, the steam and air must have free vent at the overflow to raise the water. Sometimes when the suction becomes very much heated by the time it reaches the inspirator, and will not condense the steam, the water will come up into the inspirator but will not pass through the jet. The simplest way to overcome this trouble is to shut off the steam and let the water down, this will cool the instrument and suction, and the steam can then be let on again, and the water be got without difficulty. When the water is got but cannot be sent into the boiler, in nearly every case this trouble is caused by not giving it water enough. It is caused by having the suction pipe too small, so that the lifter does not supply the forcer with water enough to condense the steam on the forcer side, hence the inspirator refuses to work; sometimes owing to a leaky steam valve, the first water that comes is very hot, and then the forcer cannot take it as it will not condense the steam; when this is the trouble let the water run out at the overflow until it becomes cooler, then the forcer will take it, and send it to the boiler. It is as well to see that the check valve on the boiler is not set fast, and that it rises sufficiently so as not to choke the delivery. The delivery pipe should also be as large as the inspirator connections. The pipes should be well blown out before connections are made, because red lead used in making the pipe joints becomes detached, and is blown as soon as steam is turned on, into the inspirator, filling up the jets and rendering it imperfect in its operation. It is preferable to have a free passage to the water, so that the suction will empty itself when the steam is shut off; thus cooling the inspirator by drawing the air through it, as it rushes in to fill up the suction vacated by the water.

It is best to have an inspirator fitted, of just the right capacity to feed the boiler by keeping it going constantly.

THE SCREW PROPELLER.

The screw, as applied to marine propulsion, is merely an endless screw working into an endless nut (the nut being the water of the ocean), the diameter of the boss being the body of the bolt at the bottom of the thread, and the blades the thread. The screw being revolved in the direction of its pitch, bears or thrusts with the after face of its thread,

against the corresponding or forward face of the thread in the nut, and is driven ahead in a forward motion at a speed according to the degree of fineness of the pitch, and the power applied. Or, to take an apt illustration, exactly as the action of an auger in the hands of a carpenter when boring into a block of wood; but as the water into which the screw is impelled is a yielding medium, which gives way, appreciably, to the impact of the screw; or, in other words, the thread of the nut is defective, the screw slips perceptibly from its work, and the forward motion is less than the full amount of the pitch. This slip is called propeller slip, or slip of the screw, and generally averages from 10 to 20 per cent. In contradistinction to propeller slip, is the somewhat anomalous term of negative slip, or the fact of the vessel, being propelled; actually progressing at a quicker rate, than the rate at which the screw would advance if the water was a solid nut, and not a yielding liquid. Negative slip seldom occurs, and by many is not believed in at all. However, it can only occur when by wind, tide, or current, the ship is propelled at a greater speed than the pitch of the screw and the speed of the engines can overtake, consequently the screw drags through the water, and, to a certain extent, holds the ship back. If negative slip should otherwise occur, it must simply be owing to faulty design in the construction of the stern lines of the ship, or the propeller is not in proportion to the work required of it.

Terms and Explanations relating to Propellers.—The *axis* of the screw is the imaginary centre line through the shaft in a fore-and-aft direction, and upon which, the propeller may be supposed to revolve. The *radius* of the screw is half of the diameter, or a radial line running from the centre toward the outer edge or periphery of the screw. The *length* of a screw, is its length on a line parallel with its axis, or measured on a line in the direction of the shaft. The forward edge of the blade, is the *leading edge;* the after edge, is the *following edge.* The *radial length* of a blade, is its length measured from the outside of the boss to the periphery in the direction of the radius. The *pitch* of a screw, is the distance apart, on the length of the bolt that one turn of the thread takes up, or the distance from tip to tip of one convolution measured on a longitudinal line parallel with its axis or direction of its length; and accordingly for every turn or revolution of a screw in a solid nut, the screw or nut (according to which is fixed or stationary), will advance to the amount of its pitch. Could a turn or convolution of the thread be unwound from the rod or spindle forming the body or centre of a screw, and be laid flat, it would take the form of a right-angled triangle, the base being the circumference, the perpendicular the pitch, and the hypothenuse the line that would delineate the top of the thread. The length of a propeller blade or thread is part only of a complete convolution, a convenient fraction of the circumference, generally from $\frac{1}{6}$th to $\frac{1}{10}$th, therefore in a single-threaded screw a propeller would only have one blade, so it is at once evident that two, three, or four threads are required, which, if kept parallel to each other, may be wound round the cylinder in the same

manner as one. Propellers having two blades give the best result, so far as speed is concerned—that is to say, they have least slip, and many cases could be noted where three and four bladed propellers having by misadventure lost one or perhaps two of their blades, have propelled their respective ships at a faster speed than previously when the propeller was complete. But propellers with three or four blades give a steadier motion and much less vibration, especially in a heavy sea-way or with a light draught of water (when the screw is not sufficiently submerged), and are therefore usually adopted. A *true screw* has the pitch uniform throughout every part of the blade. When the forward part has less pitch than the after part of the blade, the screw is said to have a *varying* or expanding pitch *longitudinally;* and when the outer part has a different pitch from the inner part of the blade, the screw is said to have a *varying* pitch *radially*. The after or flat face of the blade is called the *driving surface*, and the forward or rounded back of blade the *drag surface*. The *angle* of a screw, is the acute angle, included by a plane at right angles to the axis, and the driving surface of the blade. The angle varies throughout with every radius less than the complete radius. The *oblique area* is the actual area of the driving surface measured obliquely. The *centre of pressure* is that portion of the blade around which the forces exerted by the blade will counter-balance each other. A screw is said to be *right-handed* when the upper blade turns from port to starboard when going ahead, or from left to right, when looking forward from the rudder. The reverse is a *left-handed* screw. Right or left handed screws are used according to which direction it is desirable to run the engines. The *effective area* of the blade is the projection of that blade, as seen on a plane at right angles to its axis. The *disc area* is the area of the circle due to the screw's diameter. The *helix* is the spiral line described by the blade in its onward progression through space.

Experiments with the Screw Propeller.—Messrs. Yarrow & Co. made a series of experiments with propellers in order to determine the most suitable screw for their torpedo boats. These experiments embrace trials with twenty-five propellers, varying in diameter, pitch, and blade area. As each trial was conducted progressively, in order to obtain comparisons of efficiency for each screw at different speeds, and as the speed eventually obtained was the highest ever recorded, namely, 21·9 knots, or over twenty-five statute miles per hour ; these results are of great value, forming a valuable contribution to the general knowledge on the subject, as will be seen from the following conclusions.

1st. The trial indicated that at speeds over eighteen knots, the resistance does not increase in the very rapid ratio in which it is commonly supposed, thus promising a possible increase of speed in the future.

2nd. A very remarkable fact which was ascertained during the experiments, was the influence which the elasticity of the propeller blade had on its efficiency ; and this was confirmed without exception and in a most marked degree, the thin and elastic blade in every case giving a superior

result to a rigid blade. Results were obtained from two screws of precisely the same diameter, pitch, and area, excepting only the thickness of the blade. It was found when running at a speed of 16 knots, that the tip of the thin blade bent forward during one part of the revolution to the extent of 1¼ in., and at a speed of 17 knots it bent forward 1¾ in., and at a speed of 18 knots it bent 3 in., coming back when at rest to its original shape; beyond this speed the blades became permanently bent. It is reasonable to suppose that in an efficient screw, the work done by any one blade should be equal to that done by each of the others, also that it should be uniform throughout the revolution, and it is not improbable that the elasticity of the blades tends to conform to these conditions, and further, if it is proposed in designing a screw to turn to good account this elasticity, the blade should be proportioned so that in bending forward its pitch should be reduced, which will be a means of further equalising the work done by each blade. The builders question whether during certain portions of the revolution there is not actually a pressure on the back of the blade in the opposite direction to the motion of the boat when propellers are used having little slip, and of large diameter and high speed.

3rd. A noticeable feature was more or less confirmed throughout the experiments, namely, that screws of most efficiency were those which had least variations of slip at different speeds, while on the other hand those having at a slow speed a negative, or a very small slip, were without exception, bad.

4th. In two opposite cases of screws, one large in diameter and of fine pitch, the other small in diameter and coarse in pitch, although so different, actually were productive of almost the same results, and when taken in comparison with the others were clearly extreme cases, both representing propellers of inferior efficiency, suggesting that the best screw would be one proportioned somewhere between the two, which was eventually found to be the case.

5th. One fact proved by these experiments is, that propellers giving the best results at high speeds are not the best for slow speeds.

6th. The experiments proved most conclusively, the importance of proportioning the propeller to suit the conditions under which it works, and the loss that may be occasioned through not doing so.

7th. With the most satisfactory propeller of all those tested, with which a speed of 23 knots was obtained with about 520 horse-power, showed the resistance of the boat apparently augmented in a less rapid ratio than the cube of the speed.

Form of Propeller.—The propeller used by Messrs. Halsey & Co. is a three-bladed screw, with steel boss and blades, the shaft being also of the same metal. Each blade is let into the boss and keyed in separately endwise, so as to admit of a fresh blade being readily inserted in case of damage. If, however, the propeller should strike a spar, the shock would probably only double it up, and the vessel would be able to proceed with the other two. The screw is composed of four different pitches, its design

being the result of much study and calculation. It is arranged with a wave-line entrance, so as to take the water line like the bow of a vessel. The extreme ends fo the blades are curved, so as to prevent the water from being disturbed in the line of centrifugal force, and thus cause a column of water to be thrown out at the stern.

The Indicator.—The Steam Engine Indicator is an instrument for reproducing the action of the steam through the engine, and indicating it, upon a card, from which, can be deduced the power exerted by the engine. Richard's Indicator is in most general use for this purpose; it is composed of a small steam cylinder, to the piston of which, steam is admitted to one side, only; upon the other side is fixed a resisting spring loaded to the working pressure suitable for the engine. A pipe connection is made to one or other of the sides of the engine piston; upon communication being opened the indicator piston rises and falls with the fluctuating pressure in the engine cylinder. A pencil attachment being fixed to the piston-rod of the indicator, marks or describes the varying pressure upon a slip of paper, wound round a brass barrel, which is made to revolve to and fro, in correspondence with the stroke of the engine—the pencil thus indicates the pressure throughout the stroke, in accordance with the expansion of the steam in the cylinder.

In taking indicator diagrams, the indicator is screwed on to a pipe-fitting, fixed for the purpose to the engines, and communicating with the top and bottom of the cylinder; a threeway cock admits steam from the top or bottom as may be desired; a cord attachment to the barrel of the indicator is looped on to some reciprocating part of the engine such as the air pump levers, which will represent the stroke of the engine, proportionately reduced to suit the indicator, an attachment for the purpose being generally supplied. When the cord is properly adjusted to the stroke of the indicator, and the barrel is following the motion, the pencil is applied to the paper for a few strokes, which produces a horizontal straight line, which line is the atmospheric line of the diagram; steam is then admitted, and at the beginning of a stroke, the pencil is again pressed against the paper on the barrel, and retained there throughout a complete revolution of the engine; a diagram is thus described illustrating the action of the steam in the top or bottom of the cylinder, as the case may be; it is then taken off and another slip of paper put on, the indicator being stopped meanwhile by unlooping the cord; and another diagram is then taken from the other side of the piston. These two diagrams are marked top and bottom respectively, and put aside for calculation—the pressure on the steam gauge, the number of revolutions, and the state of the vacuum being noted. For expediency the diagrams from both ends of the cylinder are usually taken on one slip of paper, the one over the other; they are thus more readily compared with each other.

A metallic paper is generally used, so that the diagram can not be afterwards tampered with, a brass point being used for the pencil.

To calculate the horse-power from the diagram, the card is divided into

ten equal divisions by vertical lines or ordinates, the length of each of these divisions is measured off with a scale, supplied with the instrument; the measurements are added together and the total divided by 10, which gives the mean of the measurements, or the mean pressure of the engine throughout the stroke. The mean pressure is then multiplied by the area in square inches of the cylinder from which the diagram was taken, and by the piston speed (that is the number of revolutions per minute, multiplied by twice the length of stroke in feet), and the product divided by 33,000, which gives the Indicated Horse Power of the Engine. If there are two cylinders, of course, each cylinder is taken separately, and the results added together for the total I.H.P.

33,000 lbs. raised one foot high per minute being the standard horse-power assumed by Watt, and now generally adopted.

However, in working out the power of an engine from a diagram, a shorter method may be used; by working out a constant from the known factors previously, as explained hereafter.

Rule for Calculating Indicator Diagrams:—

$$\frac{\text{Area of cylinder} \times (2 \text{ stroke})}{33{,}000} = \text{constant.}$$

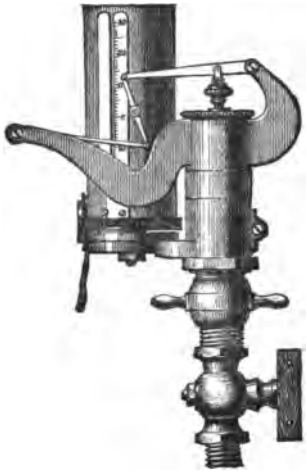
$$\text{Constant} \times (\text{mean pressure} \times \text{revolutions}) = \text{I.H.P.}$$

Rapid Method of Working out Indicator Diagrams.—When a series of diagrams are to be taken from the same engine or pair of engines, the constant for each cylinder may be worked out previously and kept at hand, to be available when diagrams are required. Then the mean pressure and the number of revolutions are all that are necessary to be taken, which, multiplied into each other, and again multiplied into the constant, gives the indicated horse-power of that particular cylinder.

However, the computation may be again materially shortened, by curtailing the method of adding up the various pressures on the ordinates to obtain the mean. For instance, if a long paper scale, say a foot long, be made from the scale supplied with the indicator, the sum total of the pressures may be obtained without the use of addition at all, by placing the scale thus made upon the first ordinate of the diagram, in the usual way, and measuring the length of the first division, then shifting the scale to the second ordinate and starting at the point on the scale where leaving off on the first, and measuring the second division, then again shifting to the third ordinate and again measuring from the point on the scale where leaving off on the second ordinate, and so on, until all the ordinates have been measured; when the sum total can be read off on the scale at a glance. If there are ten divisions on the card, by pointing off a figure on the left, of course, will be equivalent to dividing by ten, which gives the mean of all the pressures. In following this method it is a good plan to provide several slips of stiff paper, of the same length as the scale, and when taking diagrams to mark off with a pencil the pressures on to the slip in one continuous length, as before, that is, with the slip laid on the

first division of the card, mark off on the edge of the paper the length of the division, beginning at the exhaust side, then shift the point marked on the steam side, to the exhaust side of the second division; then again mark the length to the steam side, and so on successively until all the lengths have been obtained, which then can be measured with the scale at one operation. Or the slips can be marked with the number of the card, and laid aside until fitting leisure can be had for calculating the power indicated. When the power developed is wanted hurriedly, two persons, or even three, can assist in the operation, one dividing the diagram into ordinates, one measuring with the slip, and the other multiplying the results together.

If more substantial scales are preferable, steel, box, or ivory scales may be had to order from various makers.



RICHARD'S INDICATOR.

Richard's Indicator.—While for many years Richard's Indicator has held a high place in the estimation of engineers, it could not, until recently be considered perfect. Much annoyance and loss of time was experienced when diagrams of engines were being taken, and especially so in the case of marine engines, when the sea was rough and the boiler priming, by the water and grit spurting through the atmospheric holes in the cylinder cover of the indicator. In this way the diagram cards were frequently destroyed, and at all times the operation was attended with much uncertainty. Messrs. Hannan & Buchanan, who have made several hundreds of these indicators, and are the sole makers in Scotland, bestowed considerable attention upon this deficiency of the instrument, and the result of their labours is most satisfactory. The improvements they have made upon the indicator, render it as perfect as possible, and so

simple is the modification of the principle involved, that it is a matter of wonder that the ideas they have so successfully worked out were not before now conceived. The holes have been removed from the top of the cylinder, to a more convenient part of the indicator, and the construction of the cylinder has been materially altered to suit the new arrangement of the holes. Gutters are cut round the inside boss of the swivel-arm of the indicator, and two holes are bored in the casing of the cylinder. One hole is opposite this gutter when the arm is full out from the paper drum, and the other when the indicator is in a position to take a diagram. A third hole is bored through the boss of the swivel-arm to communicate with the gutter inside; this hole comes opposite the two holes in the casing as the arm is moved towards the paper drum, so that the water has a free flow in whichever position the arm is placed without in the slightest degree soiling the diagram sheets. This improvement is a valuable one, and engineers and others, since it has been effected, have not been slow to submit their indicators to be altered to the improved style.

To Test Richard's Indicator.—A simple means of testing these instruments is to make the instrument mark off its own scale. By so doing, the accuracy of the parallel motion and the varying elasticity of the spring, are gauged at each point in the movement of the pencil.

To accomplish this, all that need be done is to turn the indicator upside down and grip it in a truly vertical position in a vice. Then put a rod down the tube till it reaches the piston, and on this rod successively place a number of accurate weights corresponding to the various divisions of the scale, allowing for weight of rod and spring, and as each weight is in position, mark off the scale on the drum with the needle of the instrument. When the working pressure is low, the weight of the piston, &c., must, of course, be allowed for.

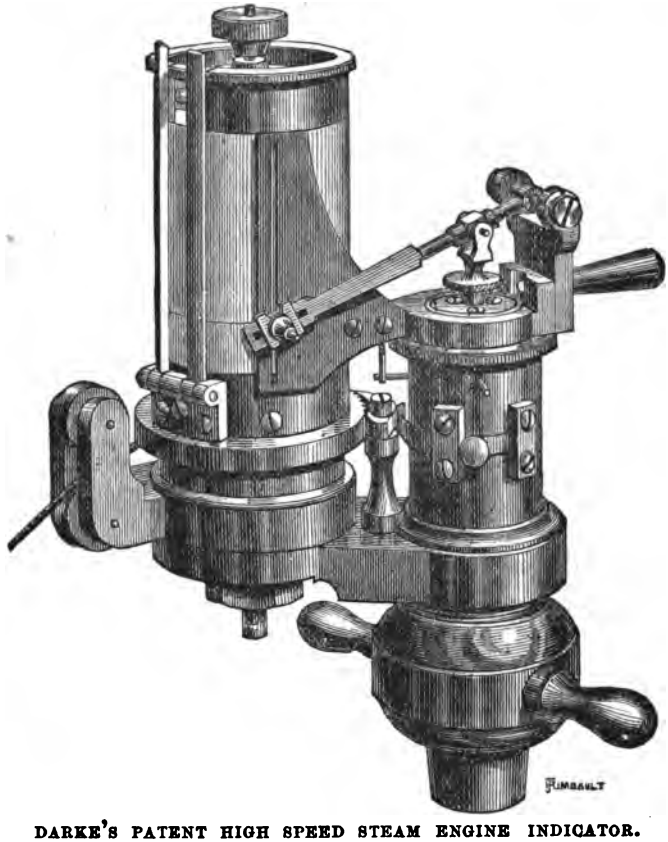
Sometimes a slight difference is found, and a correction required at each end of the scale when compared with the usual wooden one supplied with the instrument."

Darke's Patent High Speed Steam Engine Indicator.—This improved indicator of which Messrs. Elliot Brothers, London, have the right of manufacture, is an instrument designed expressly for quick running engines, such as those of torpedo boats, &c.

In this High-speed Indicator an entirely new pencil motion is used, which is perfect in theory and decidedly superior in practice to any motion before introduced, both from its accuracy, lightness, and freedom from slackness, and liability to wear at the most important part, viz., the piston-rod head. This motion is formed by a single light steel lever, carrying at the one end a cross-head moving upon steel centres; to this lever the motion of the piston is communicated by a jaw, fitted on the piston-rod head, which jaw supports, between its centres, a sleeve through which the lever slides with the varying angle of the motion of the lever. The metal pin (forming the pencil) is carried by a block sliding upon the other end

of the lever, the pin being kept in a line, parallel to the axis of the paper drum, by a slot guide placed between the sliding block and the paper drum, in which slot the pin moves. The pin is kept against the paper by the elasticity of the lever. The action of this motion has been found to be so superior that Messrs. Elliot Brothers have decided to apply it to all their indicators.

In addition to this lighter motion, lightness of the other moving parts of the High-speed Indicator is secured by making the size of the piston ¼ square inch in area, by decreasing the diameter of the spring from centre to centre of the wire, by making the piston-rod hollow, and by carefully lightening all the moving parts in every possible way.



DARKE'S PATENT HIGH SPEED STEAM ENGINE INDICATOR.

The paper drum is also smaller and lighter, and is made hollow in order that the paper may be supplied in continuous sheets, and drawn through a

slot from a roll in the interior of the drum, and torn off, after each diagram is taken. This arrangement does not prevent the paper being used in small separate sheets as before.

These small indicators are about half the size and weight of the ordinary Richard's Indicator, and from the greater convenience of carriage, and accuracy, are strongly recommended.

They are made in pairs, right and left handed, if required, and neatly packed in one case.

Nominal Horse-Power.—*What it Represents.*—The standard horse-power of 33,000 lbs. raised one foot high per minute was assumed by Watt, from repeated trials. He found by experiment that a horse treading a mill path at the rate of 2½ miles an hour, working 8 hours a day, would, on an average, raise about 150 lbs. by a cord placed over a pulley; which is equivalent to raising 33,000 lbs. one foot high in a minute. This is rather a high average, and authorities differ very much on the subject; still, there is no doubt but that Watt experimented with the best class of draught horse procurable, and none but horses of superior breed could stand the test for any length of time. The average ordinary performance of a draught horse doing useful work, as on a level road drawing a cart, is found to be 432 ft. lbs. per second—equal to 0·785 of the value assigned by Watt, or 25,920 lbs. per minute, at the rate of 216 ft. per minute, working eight hours a day. Watt's steam engines were calculated to work at the rate of 44,000 lbs. per horse-power, (the power of a horse according to Desaguliers,) but he allowed only 33,000 lbs. in his calculations, considering the difference due to friction. Boulton and Watt ultimately estimated the horse-power at 32,000 lbs. Tredgold reckoned it at 27,500 lbs., and Smeaton at 22,916 lbs. However. the standard of 33,000 lbs. answers the purpose sufficiently well in calculating powers of engines, and has the merit of being a simple divisor: there is no palpable reason why it should be altered, and therefore it is adopted generally. If a 10-horse engine be worked continuously for 24 hours, its work would be equal to 30 horses, each working eight hours a day, provided the power of each horse be taken at 33,000 lbs., and the power of engine given be indicated horse-power. The term nominal horse-power resulted from the assumption that a fictitious mean pressure of 7 lbs. on the square inch was equivalent to the average pressure throughout the stroke of the old low pressure condensing engines. In these days of high pressures, other fictitious mean pressures have to be assumed for every, or any, grade of expansion a particular engine may require; otherwise the power exerted is more than the calculated or nominal power originally fixed upon. Hence the discrepancies between the nominal and indicated horse powers of engines by different makers. If this were followed up explicitly—that is, adopting a suppositious mean pressure corresponding to the initial pressure and the rate of expansion for every given or proposed engine—we arrive at theoretical effective horse-power, and it is nominal power no longer; therefore it becomes obsolete and out of date. But it is seldom calculated

at all. If so, it is generally made about a fifth of the intended indicated power, but much oftener guessed at. In reality, nominal horse-power is merely a commercial phrase, and may mean anything or nothing, according to the position the engineer may be placed in with his contract. If he wishes to show a high result on the trial, he will call it a very low nominal horse-power; so we see in the newspapers glaring accounts of engines upon their trial working up to eight or ten times their nominal horse-power. On the other hand, if the object is to get as high a price as possible for a small engine, it is called a high nominal horse-power, and so on. There are many other similar cases, all tending to confuse transactions in engineering matters, and showing that the term ought to be abolished as mischevious. When the pressure is not taken into account it can be of no use as data whatever. The best engineers take no notice of nominal horse-power, as they always know approximately what the indicated power will be, and work accordingly. The admiralty have also given it up, and specify indicated horse-power instead. Nominal horse-power is still more recklessly applied to boilers; and it ought to be the duty of every conscientious engineer to lend his aid to expunge the antiquated and useless term.

The generally accepted standard or rule for the nominal horse-power of a compound engine, is to square the diameter of both cylinders and divide by 30.

The Organ Steam Whistle.—The Organ Steam Whistle is a speciality well adapted for steam yachts, &c. This steam whistle claims many advantages over the ordinary bell whistle. Owing to the simplicity of its construction it does not get choked as frequently happens with the latter named whistle, and is not liable to be disordered. Its shape assumes that of an organ pipe, hence the name, and the sound under the force of steam is loud and resonant, eclipsing the shrill, sharp, tone of the common steam whistle. For all the requirements of ocean and channel service these whistles are admirably adapted. In fitting a steam whistle, it should be placed forward of the funnel and as high as possible, and should be above, and clear of, or in front of, any deck houses, &c., that is likely to obstruct the sound. It is obviously of no use to supply a steam whistle and then place it behind a house, funnel, or ventilator, or any erection likely to deaden the sound.

Surveys of Machinery.—When the machinery of a steam vessel or yacht is surveyed under the Board of Trade regulations. The machinery to be surveyed comprises the engines and boilers used for propelling the vessel, and all the machinery connected therewith. The parts to be taken to pieces for examination prior to obtaining declarations for any period exceeding six months are;—1st. To have the upper brasses of all bearings taken off. 2nd. The shaft turned round and carefully examined. 3rd. The cylinder covers and junk rings lifted for examination of the pistons and cylinders. 4th. The slide covers removed for examination of the

slides, and if necessary the slides taken out. 5th. The air and circulating pump covers lifted for examination of the pump, buckets, and valves. 6th. The covers of all feed and bilge pump valves removed for the examination of the valves. 7th. All discharge valves and sea cocks taken out for examination. 8th. The propeller shaft to be drawn when necessary, and it and the screw to be examined; and in all cases in which the shaft is drawn, it is to be seen again after the screw is secured in its place. 9th. The bridge and fire bars to be removed to permit of a thorough examination of the boiler and furnaces. 10th. All cocks and valves on the boiler to be taken out and examined. After the examination of the parts has been made as above, the machinery must be tried under steam at full pressure.

It will rest with the owners to determine whether or not they will have a certificate for any period exceeding six months; but if they do so determine, then the above instructions are to be complied with before a declaration is granted.

The boiler of all new passenger vessels, passenger tugs, and other small passenger vessels, should be fitted with separate feeding arrangements in addition to, but unconnected with the main feed pipes and valves. In very small vessels an efficient hand pump, instead of the donkey pump may be passed, if the surveyor has satisfied himself as to its efficiency when steam is up, and provided there are separate feed pipes and valves as directed above. The practice of using the same pump for the bilge and for feeding the boiler should be discouraged.

To Ascertain the Cubic Contents of Ship's Boats.—The Board of Trade rule to obtain the cubic contents of boats, is to take the length and breadth outside, and depth inside, measuring from the bottom of the row-locks, and to multiply them into each other, then to multiply by 6, the product will be the cubic capacity of the boat in feet.

A life boat fitted with efficient and substantial air casings is deemed to be capable of carrying one adult person for every 10 cubic feet of her capacity. A square sterned boat will not be passed as a life boat. Zinc is not permitted in the construction of a life boat or her air casings, neither is copper to be used if the boat is built of iron. If galvanised iron is used, it should be well done, otherwise it is nearly as bad as zinc. No boat fitted with a steam engine will be passed as a life boat.

Board of Trade Regulations Regarding Steam Launches.—As regards steam launches, or boats fitted with steam power, the contents taken up in the boat by the engine and boiler are not to be deemed part of the clear contents of the boat. As regards the safety valves fitted to the boilers of steam launches, it should be seen that the boilers are provided with safety valves out of the control of the engineer when steam is up. The lifting or easing gear for the valve should actually lift the valve, and not merely the weight. The boiler should also have a steam gauge, a glass water gauge, and test cocks.

Penalty Regarding the Undue Weighting of Safety Valves.—If any person places an undue weight on the safety valve of any steam ship, or increases the weight beyond the limits fixed by the Board of Trade Surveyor, he shall, in addition to any other liabilities he may incur by so doing, incur a penalty not exceeding one hundred pounds.

The Area of Safety Valves.—The area of each safety valve on the boiler must not be less than half a square inch per square foot of grate surface. In new vessels, or vessels which have not previously received a passenger certificate, no safety valve will be passed less than three inches in diameter.

Care should be taken that the safety valves have a lift equal to at least one-fourth their diameter; that the openings for the passage of steam to and from the valves, including the waste steam pipe, should each have an area not less than the area of the valves; and that each valve box has a drain pipe fitted at its lower part. Unless there is a proper lift, and free means of escape of waste steam, it is obvious that the effect is the same as putting on an extra load.

SMALL STEAM VESSELS.—(GENERAL DESCRIPTION OF VARIOUS CLASSES, AND RECENT EXAMPLES.)

Iron Steam Yacht "Britannia."—The "*Britannia*," is a small iron screw yacht, lately built for Windermere Lake, and considered a remarkable success, both in appearance and speed, by all who have seen her as well as her owner and builders. She was built by T. B. Seath & Co., shipbuilders, Rutherglen, for Major G. J. M. Ridehalgh, Fellfoot, Windermere. The yacht sails on the lake, having been taken thither in pieces and put together and launched from a slip at Fellfoot. Her dimensions are as follows :—

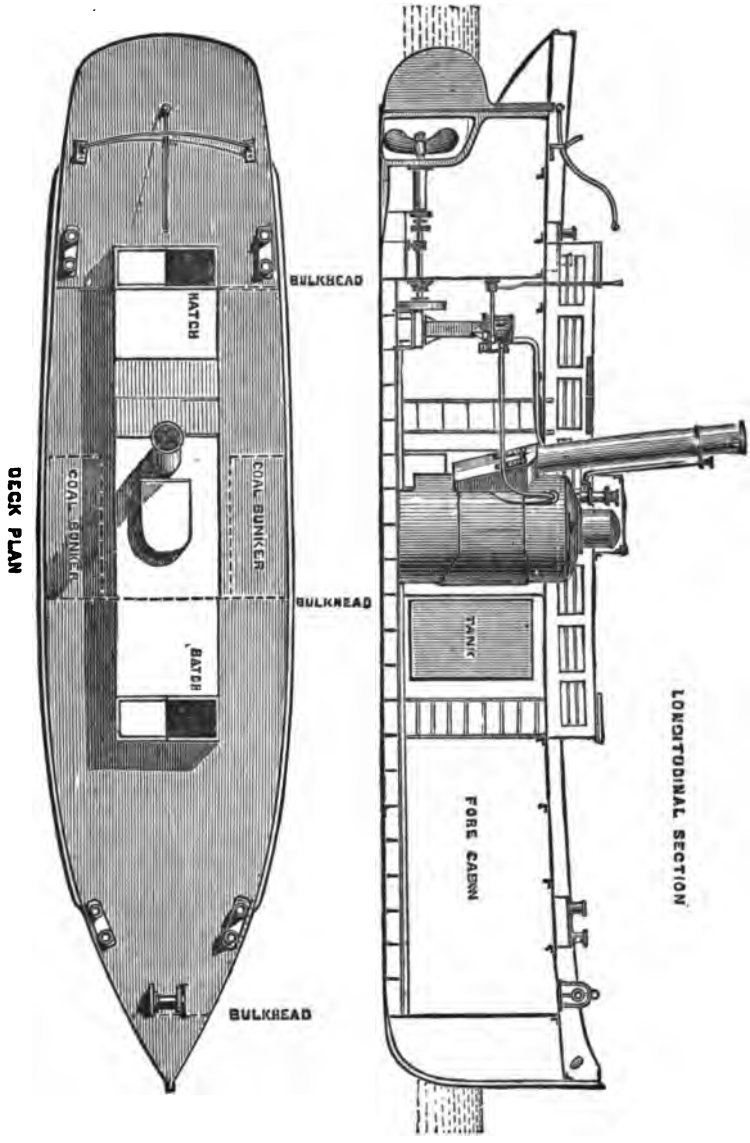
Length, extreme	107 ft.
„ on water line	96 „
Breadth, moulded	12 „
Depth, „	7 ft. 6 in.
Tonnage, T.Y.M.	64 tons.

Draft, forward, 4 ft. 3 in.; draft, aft, 6 ft.; displacement, 65 tons; area of immersed midship section, 41 sq. ft. Engines: Inverted direct-acting, non-condensing; two cylinders—10 in. dia., and 12 in. stroke, with link reversing gear; steel shafts; propeller—four bladed—5 ft. dia., and 8 ft. 6 in. pitch—surface of blades 10 ft.; revolutions—180 per minute. Indicated Horse-power of Engines: 100. Boiler: horizontal tubular, of steel, 7 ft. long by 6 ft. 6 in. diameter, with 2 furnaces and 72 tubes. Total heating surface, 350 sq. ft.; working pressure of boiler, 120 lbs. per sq. in., tested to 200 lbs. per sq. in.; consumption of coal, 2 cwt. per

hour; and speed, as guaranteed by owner, 16 statute miles per hour. The yacht which has a handsome appearance is fitted with two masts, the funnel stands about one third of her length from the stern, and she has a fiddle head clipper bow, with bow-sprit. Of the internal arrangement there are four cabins; well forward and immediately aft of the chain-locker and store-room is the owner's cabin, fitted with double seats, desk, two lockers, w.c., and wash stand, racks, &c. Aft of the owner's cabin is the general cabin, with seats on each side and a central table; in the four corners of the cabin side-boards are fixed, also one in the centre at the after end. Between the general cabin and ladies' cabin, which is forward of the boiler room, is a lobby, which also contains a seat and table on the port side; and on the starboard side the pantry, sink, table, &c.; while in the centre the staircase leads from the deck. The ladies' cabin is seated all round excepting at the doorways, &c., and contains a wardrobe with double doors, a davenport, side-board, wash-stand, and w.c.; an octagonal table stands in the middle of the cabin. Aft of the engines is the smoking-cabin, with seats on each side, side-board, and two lockers, and a separate stairway on deck. All of the cabins are luxuriously panelled and cushioned, with elegant ornamentation and fittings. The engine room is also furnished with seats. The rod of the starting gear of the engines, which is vertical, leads up to the deck and is fitted with a hand wheel, so that the engines may be worked from the deck as well as from the engine room. The internal arrangement of the "*Britannia*" is exceedingly well designed, the space available having been made the most off.

Large Cruising Steam Yacht.—The engraving on page 2 represents a fine type of large cruising steam yacht, built of steel, in accordance with Lloyd's rules, and fitted with compound surface condensing engines and multitubular boiler. She is from the design supplied by the Abercorn Shipbuilding Company, Paisley.

Sea-Going Steam Launch.—The engraving of steam launch on page 16 represents a fast steam launch, built of steel, also by the Abercorn Shipbuilding Company. This type of vessel is to be recommended, *i.e.*, if speed is requisite. The launch is fitted with cabins and other accommodation for passengers, w.c., pantry, galley, &c., and is fitted with masts and sails, as shown; these are of considerable assistance, especially in rough weather. The decks are of East India teak; the skylights are also of teak, the glass being protected by neat brass guards. There is fitted all round the launch a galvanized hand rail, also a galvanized windlass fitted forward for lifting the anchor. The engines are on the compound surface condensing principle. The principle parts of the engines, as the boiler, are made of mild steel; and all brass work of gun-metal. The propeller is also of forged steel; of course, gun-metal or cast-iron could be substituted if required, but forged blades are exceedingly strong, and are less likely to get knocked away or broken. An awning, very necessary in hot climates, is fitted up fore and aft. The engine and boiler space is covered



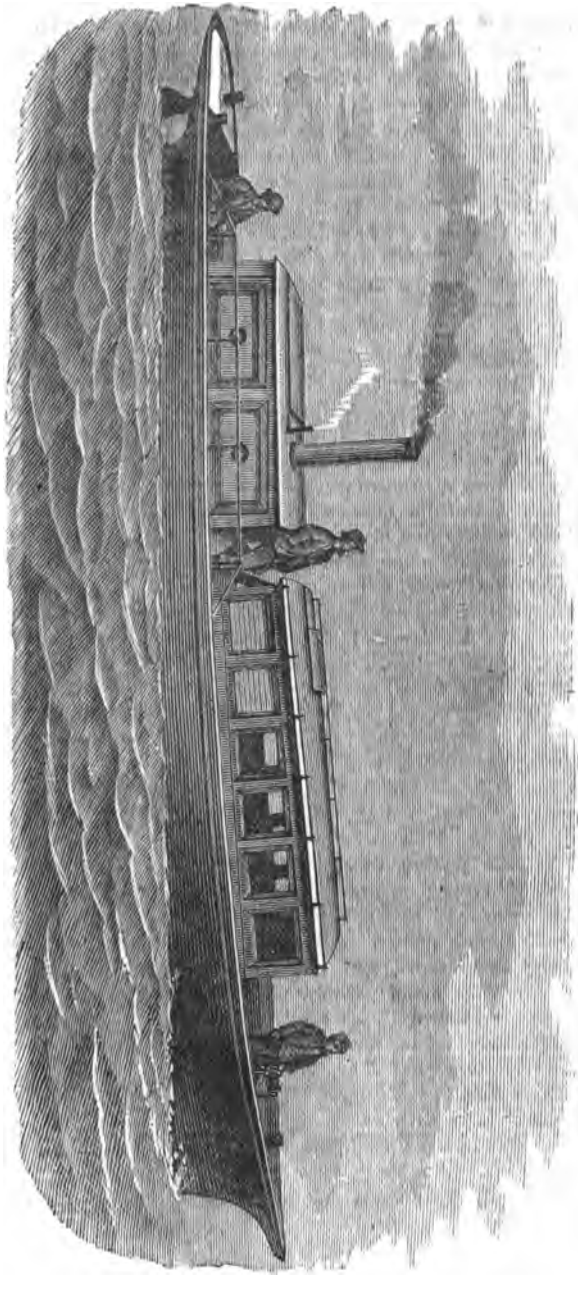
PASSENGER OR CARGO LAUNCH.

over with gratings and fitted with air-tight skylights, the object being to keep the engine-room and stoke-hole as cool as on deck; at the same time to cause a forced combustion, which is very essential in many cases, such as having bad coal or inefficient firemen. The speed of this class of vessel will vary according to the power of machinery fitted from 8 to 26 miles per hour.

Passenger or Cargo Launch.—The longitudinal section and deck plan, on the preceeding page, represents a type of launch much used abroad for communicating between the shore and vessels lying at anchor—for carrying passengers or cargo. The particulars of a boat of this class recently built are as follows:—Length of boat, 45 ft.; beam, 10 ft.; depth, 6 ft.; built of iron and provided with iron deck, towing gear, and flat bottomed plate keel. Engine: one single cylinder, h.p. engine; cylinder 9 in. diam. × 9 in. stroke. Boiler: Cochran's patent, 4 ft. 3 in. diam. × 7 ft. 6 in. high; 85 tubes, 1¾ diam.; 124·19 ft. heating surface; working pressure, 100 lbs.; speed, 8-9 miles per hour; screw propellor, 3 ft. 0 in. diam.; built and engined by Cochran and Co., Birkenhead, for trade in the Pacific.

Steam Launch "Phantom."—The following is a general description or rough specification of a class of boat, such as the "*Phantom*," designed for passenger traffic across rivers, etc. Length over all 40 ft.; Beam outside 7 ft.; Depth inside of skin to gunwale 3 ft. 6in. Carvel built, of pitch pine copper fastened, with keel, stem, stern post, and timbers, of oak; swan stem, and counter stern; lined with fir down to the benches. Cuddy deck at each end of the boat, with doors to form lockers; seats arranged fore and aft, with cross benches in stern sheets and forward of boiler. Coal bunkers amidships on each side of boiler. Rudder fitted outside of propeller, with galvanised iron tiller. Engines, a pair of vertical inverted cylinders direct acting high pressure 5¾ in. diameter, by 6 in. stroke, fitted with link motion reversing gear, and feed pump. Boiler, of the vertical cross tube type, 3 ft. 3 in diameter by 4 ft. 0 in. high, with nine tubes; tested by hydraulic pressure to 150 lbs. and designed to work at 60 lbs. per square inch. The boiler is felted and lagged with mahogany and brass bands, also fitted with all necessary furnace and steam mountings, spring balance safety valve, with escape pipe, steam pressure gauge with double dial facing fore and aft, double set of water gauges, blow-off cock, steam whistle, blower cock, and hinged chimney. Propeller of steel, 36 in. diameter; screw shaft of wrought iron, 2 in. diameter; stern tube bushed with gun metal, and fitted with thrust bearing and collar. Steam and feed pipe connections of copper, exhaust pipe of iron; steam starting valve, back pressure valve and suction cock fitted. A set of stores, tools, spanners, and oil cans supplied.

The vessel is copper sheathed to the water line, and has a cabin forward 12 ft. long, framed of teak, with framed and glazed sashes, seats and lockers, the doors open forward into a small cockpit and aft on to the

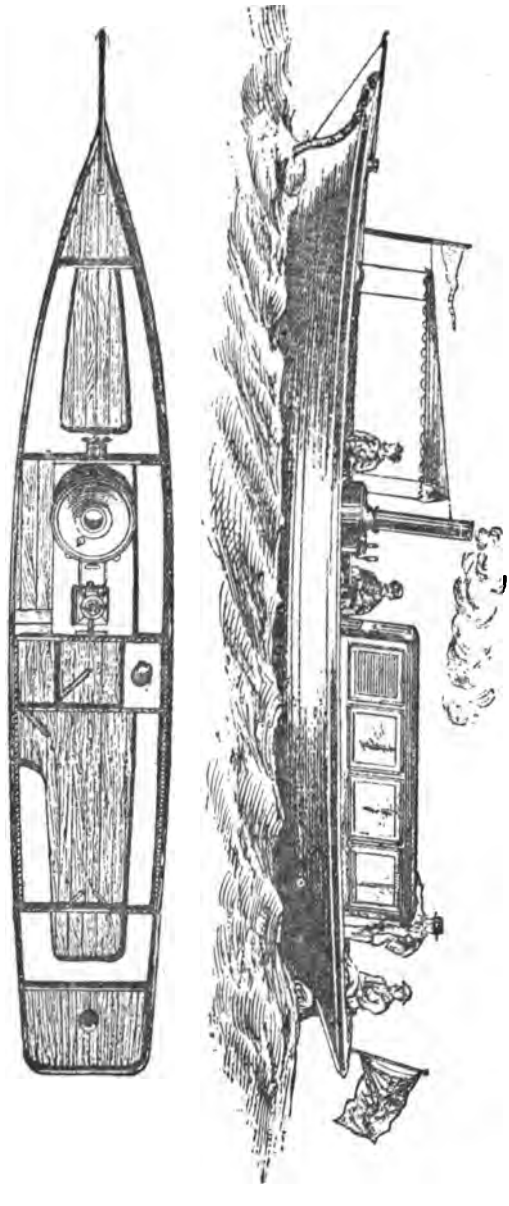


STEAM LAUNCH "PHANTOM."

gangway amidships, with companion and scuttle hatch. The after part of the cabin is divided off to form a w.c. on one side and a bath room on the other. The engine room is covered in with a framed teak cabin, with fixed round lights and scuttle hatch. Gangways are laid round the engine room, and a small open cockpit arranged aft. A No. 3 Korting's Universal Injector is fitted to the boiler with the necessary valves and pipes, also an ejector to discharge bilge water.

A galvanized Trotman's anchor is supplied with 15 fathoms chain, and fitted into a chain locker forward. A steering wheel is fitted forward, and a spare tiller to steer from stern sheets. A patent ship's closet is fitted in the starboard compartment of cabin, and a zinc sponge bath in the port compartment.

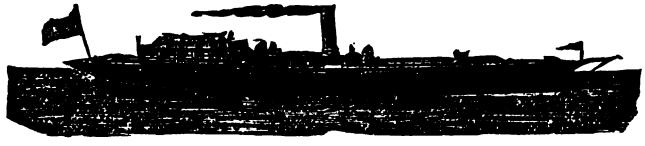
Steam Launch "Sphinx."—The general particulars of the "*Sphinx*" class of boat built as a gentleman's pleasure launch for river service are as follows:—Length, over all, 33 ft. 0 in.; beam, outside, 6 ft. 0 in.; depth, inside of skin to gunwale, 3 ft. 0 in.; carvel built of pitch pine; copper fastened, with keel, stem, stern post, and timbers, of American elm; swan stem, and counter stern; lined with fir down to the benches; cuddy deck at each end of the boat, with doors to form lockers; seats arranged fore and aft, with cross benches in stern sheets and forward of boiler; coal bunkers amidships on each side of the boiler; rudder fitted outside of propeller, and with galvanized iron tiller. The engine, a single vertical inverted cylinder, direct acting, high-pressure—5¼ in. dia. by 6 in. stroke, and fitted with link motion, reversing gear, and feed pump. The boiler, of the vertical cross tube type—2 ft. 2 in. dia. by 3 ft. 0 in. high, with 6 cross tubes, tested to 150 lbs. per sq. in., and designed to work at 60 lbs. per sq. in. The boiler is felted, and lagged with mahogany, and brass bands; also fitted with all necessary furnace and steam mountings, spring balance safety valve, with escape pipe; steam pressure gauge, with double dial facing fore and aft; a double set of water gauges, blow-off cock, steam whistle, blower cock, and hinged chimney. The propeller is of steel, 30 in. dia.; screw shaft of wrought iron, 1½ in. dia.; stern tube, bushed with gun-metal, and fitted with collar thrust bearing; steam and feed pipes of copper; exhaust pipe of iron. All necessary connections, such as steam starting valve, back pressure valve, and suction cock; a set of stoking tools, spanners, and oil can, engineer's tools, and coal hammer; mop-bucket, scrub brush, and life buoy, with name painted on. The cabin, 10 ft. long, is fitted aft, framed of mahogany, with framed and glazed sashes, seats, lockers, and table; a door opens forward, and a pair of doors opens into after cock pit. The fore part of cabin is divided off to form—w.c. and a passage to pass from cabin forward. The fore part of the launch forms an open cock-pit, with seats and lockers, and small deck in head to form chain cable locker; cushions are fitted to the cabin, and seats in forward cock-pit. An awning is fitted to cover the engine room and forward cock-pit, with light stanchions and tricing lines. A No. 3



"SPHINX."—PLEASURE LAUNCH FOR RIVER SERVICE.

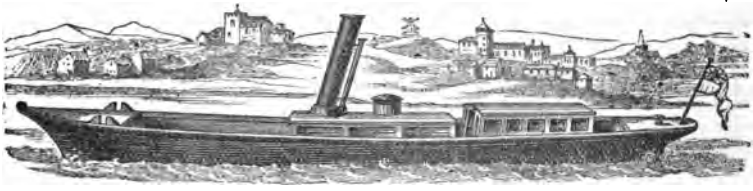
Korting's universal feed injector is fitted to the boiler, with the valves and connections ; also an ejector to expel bilge water ; a silent exhaust box is applied to the engine ; a galvanized Trotman's anchor, with 15 fms. of chain fitted into the chain cable locker in the bows ; a steering wheel is fitted forward and a spare tiller aft ; mast and lug sail, with all necessary tackle and running gear and galvanized iron shrouds, are fitted ; port and starboard side lights, mast head light, riding-light, cabin lamp, and engineer's lamp, with screens, are supplied ; a w.c. is fitted in the forward compartment of cabin with wash-stand, basin, &c.

Messrs. Miller and Tupp, the builders of the "*Phantom*" and "*Sphinx*," also build a special class of dinghey, 15 ft. long, to be carried by sea-going yachts. The specification of these are almost similar to the preceeding, except that these boats have square sterns and are without counter ; they are fitted with small horizontal return connecting rod engines, placed down in the bottom of the boat under one of the thwarts, and which occupies very little room ; the boats are clinker built, of pine, mahogany, or cedar. The principal dimensions are as follows :—Length, 15 ft. ; beam, 4 ft. 6 in. ; depth, 2 ft. 3 in. ; engine, $3\frac{3}{4}$ in. diameter of cylinder by 4 in. stroke ; boiler, vertical, 1 ft. 10 in. diameter by 2 ft. 3 in. high.



STEAM LAUNCH BY HALSEY AND CO.

Halsey's Swift Steel Launch.—This class of boat is intended for purposes in which a high rate of speed is of the first importance, such as despatch boats, express boats, for postal and other services, also for pleasure and passenger traffic. The rate of speed is guaranteed by the builders of from 10 to 25 miles per hour.



HIGH SPEED, LIGHT, DRAFT STEEL LAUNCH.

High Speed, Light Draft Steel Launches.—The engraving above represents a class of launch of this description built of steel, by Messrs. Ross and Duncan, Glasgow, and used in large numbers in

India, Africa, and the West Indies. They are sometimes sent out completely fitted together, and in other cases the hulls are in plates and frames marked ready for erection, and supplied with all rivets, bolts, metal fittings, &c, but without woodwork, which latter can often be cheaply and well supplied at the destination. In this way considerable saving of freight is effected. The hull built of steel is recommended for its great strength and lightness, so important for fast boats. These boats are built of three sizes, 60 ft., 45 ft. and 30 ft. long. The 60 ft. boats have a saloon with skylight and windows, and half-deck engine-house. The 45 ft. and 30 ft. boats are open with cockpits fore and aft. All the exposed wood work is of teak. Locks, hinges, skylight guards, rudder cap, &c., are of brass. The fittings and outfit include tiller, belaying cleats, fair leads, chain pipes, collar pipes, galvanized anchor and chain, two water tanks, ash sweeps, rowlocks, boat hook, and manilla painter; the large size of boats have also a hand winch each. Each boat has a deck awning, with its stanchions complete; all the iron work on deck is galvanized. The engines are of the inverted direct acting high-pressure class, each having two cylinders on steam hammer framing, as previously described. The boilers are of the locomotive or return-tube class made of mild Siemen's steel, with brass tubes, flanged and welded dome, and anti-primer pipe. The boilers are stayed for a working pressure of 120 lbs. per square in., and proved to double that amount.

The Torpedo Boat.—This description of boat of late years has created a sensation throughout the various powers of the world, and is now generally recognized as being a very important item in naval warfare. The British Government have given special attention to this department. From the peculiar construction of these boats and their powerful machinery they have given abundant proof that they are well adapted for going out to sea and steaming at high speeds. In fact, the highest rate of speed that has ever yet been attained by any class or description of steam vessel afloat has been made by the torpedo boat.

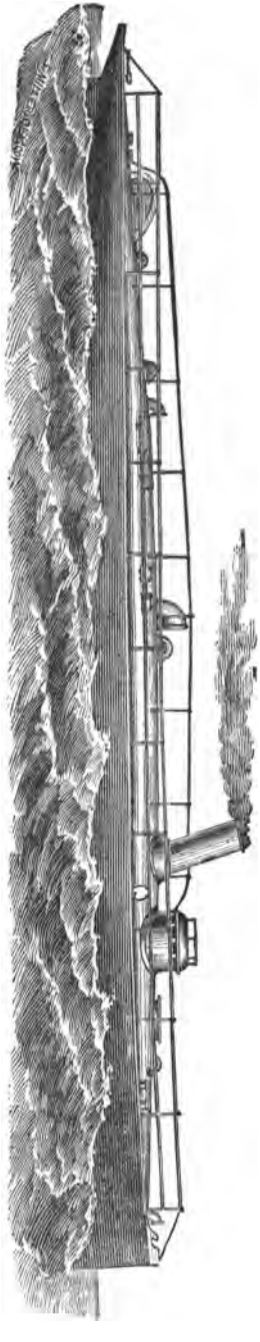
The woodcut on page 95 represents a torpedo boat built for the British Government by the Abercorn Shipbuilding Company, Paisley. The vessel is divided into seven different water-tight compartments in the following manner:—1st. Crew space; 2nd. Tower from where the steering and torpedo gear is worked; 3rd. Compartment for cleaning out tubes; 4th. Stokehole; 5th. Engine room; 6th. Cabin; 7th. Store room. The hull is built of mild steel by the Sieman's-Martin process, each plate is separately galvanized before being put together, so as to prevent oxidation.

A smaller size of boat of the same class about 60 ft. long, of the same material and workmanship, is built, but much lighter, so that it can be hoisted up by davits on board any war vessel. This class of boat is fitted with compound surface condensing engines, all the parts being made of steel so as to make it as light as possible. The boiler is of the locomotive type and is also of steel, working at a pressure of 150 lbs. per square inch,

but before being placed on board is proved to 300 lbs. per square inch by hydraulic pressure. Fresh water is used for the boiler, and an available spare supply is kept in a fresh-water tank in case the hotwell, &c., should give out. The air circulating feed and bilge pumps are driven by an auxilliary engine. In ordinary cases when a vessel requires to be stopped suddenly, the steam blows off through the safety valves, and the vessel is thus exposed, but in this class of boat the surplus steam from the boiler can be sent direct into the condenser, the auxilliary engine being kept constantly working, so that the main engines may be started ahead, or astern, at full speed, all the machinery being perfectly balanced, there is no perceptible noise even when the vessel is running at the highest speed. An auxilliary engine is also fitted for driving a fan for the purpose of giving good ventilation when the hatches are closed, and which also assists to create a perfect combustion, and keep the interior perfectly cool.

Halsey's Steel Torpedo Boat.—In these vessels every detail is adapted to its specific purpose, while all the parts are arranged so as to be as snug as possible. They make no noise in their swift passage through the water, from which they are almost indistinguishable, owing to their being painted a greenish-grey colour; and they emit neither steam nor smoke. For the prevention of the latter, Welsh smokeless coal, or coke is burnt, and air is admitted on the top of the fire grate; the short funnel is also provided with a baffle-plate to prevent the escape of sparks. There is no exhaust pipe, as a surface condenser is used, the capacity of which is in excess of all possible requirements. Though the vessel is 75 ft. long by 10 ft. beam, she weighs only from 12 to 14 tons, and can therefore be drawn up like a lifeboat on the beach, and readily launched again when required. She is built with eight watertight compartments, any two of which are sufficient to keep her afloat. Everything about the vessel, including plates, angles and stays, is of steel; the skin and also the bullet-proof armour on deck $\frac{1}{16}$ inch thick, are of crucible steel, supplied by Messrs. Samuel Osborn & Co., of Sheffield. During a test of these plates, not only was the cold plate doubled down flat with a hammer, but it was also doubled over the second time without showing any signs of fracture. This same metal is also of sufficient fineness to make knives and other cutting tools, such as plane-irons. The seams are rivetted cold with the best charcoal-iron rivets; and to perform this operation properly, men have to be regularly trained to it, ordinary rivetters being, as a rule, too heavy-handed. It has been stated that a rifle bullet will not penetrate these plates at twenty-five paces with the ordinary Snider charge.

The question has often been raised as to the action exercised by salt water on steel; and, indeed, the subject lately came before the Cleveland Institute of Engineers. The makers have not experienced any difficulty on that score; but, in deference to the fears expressed by some engineers, they have made arrangements for the erection of special apparatus for



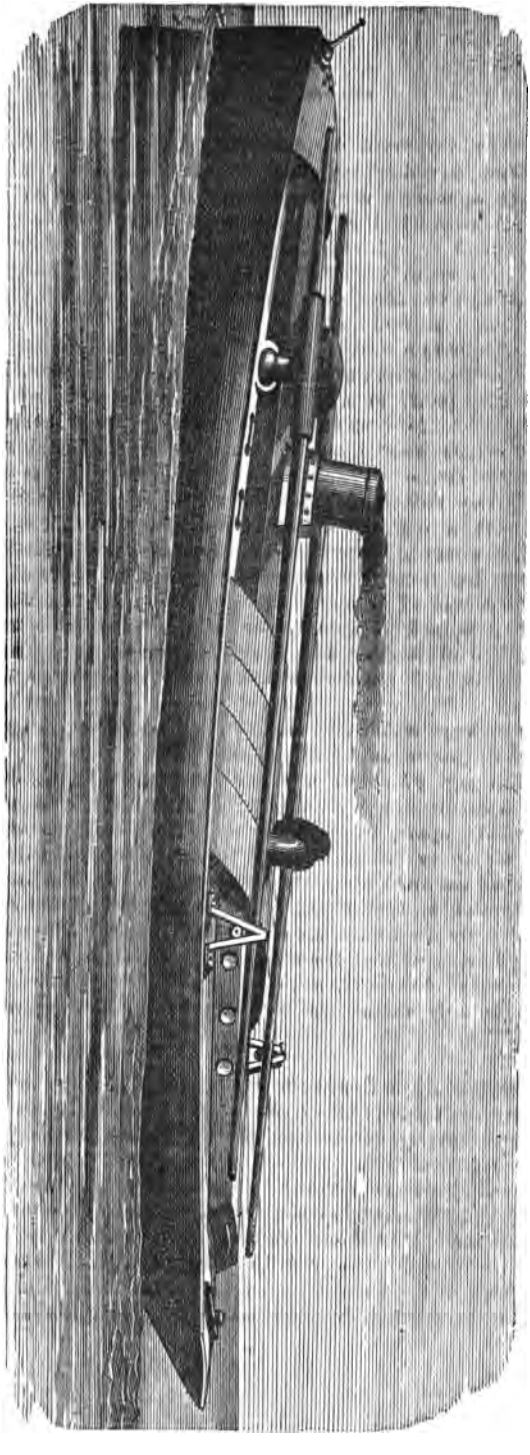
TORPEDO BOAT FOR THE BRITISH GOVERNMENT.

galvanizing the entire hull, both inside and out, thus saving the necessity of painting and its renewal.

The main engines, of about 250 horse-power, are compound, and form the subject of a patent, being very small and light, and can be got into a remarkably small space, thus giving the launches a considerable advantage. A separate engine is provided for driving the air-pump and the circulating pump of the surface condenser. In fact there are no less than five engines on board. A speed of 18 miles an hour is, we are informed, guaranteed. The engines are designed to work without any oil for lubricating the cylinders, which leads to saponification in the boiler, and a quick decay of the plates. The reason of this has been found to be that, unless a large quantity of lime be present in the feed-water so as to neutralise the fatty substance, oleic acid is set free, which acts upon the plates and causes them to disintegrate. The boiler, of the locomotive type, is capable of being worked up to 120 lbs. per square inch. Steam can be raised in about half-an-hour, but in order to provide for every emergency, an auxiliary boiler is provided, in which steam at 120 lbs. pressure can be got in a quarter-of-an-hour, long before the boat can be launched and the crew got together. This auxiliary boiler is very light, and consists entirely of heating surface. As the whole of the vessel is enclosed, it is necessary to make provision for artificial ventilation. This is secured, and the temperature of the engine room kept down by a centrifugal fan 3 ft. 6 in. in diameter, driven by a 3 inch three cylinder engine, run at about 1,300 revolutions per minute. This engine, which is similar to that made for propelling the Whitehead or fish torpedo, is made entirely of phosphor bronze. The fan, capable of maintaining a pressure equal to that of a column of water 5 inches high, is of crucible steel.

A height of only 2 ft. 6 inches appears above the water, with the exception of the sighting turret, where the officer in command takes his station. By means of speaking tubes, he has control over the whole vessel, including the engines and torpedo lowering apparatus. He also has the steering wheel in front of him, and is able to make for any object by looking through the horizontal apertures in the turret. As the torpedo is contained in a tubular casing, parallel with the vessel, and will make its object within a yard or two in still water, for a distance of 400 yards, all that is required, is to steer the vessel in the desired direction. The knuckle jointed lowering gear, which is very interesting and very ingenious, can be worked from inside the vessel without any exposure to the enemy's fire. The tube is lowered by a chain, and as soon as it reaches the water, the vessel's head is turned to the object, a valve is opened to admit compressed air into a small cylinder at the back of the tube, so as to give an initial impetus to the torpedo. On the torpedo leaving the tube it pulls a trigger, thus opening a valve and setting the engines in motion, when the deadly missile makes it way silently, though surely, direct for its object.

These vessels, however, possess other weapons of offence than the



TORPEDO BOAT BY HALSEY AND CO.

torpedo. They are fitted with means for discharging Greek fire, or crude petroleum, to a distance of about 300 ft., within a space of eighteen seconds; this apparatus consists of a cylinder affixed to the keel of the vessel. A piston is introduced into the aft end of the cylinder, and, by a screw-thread or otherwise, a compressed-air chamber of adequate capacity is attached to the same end of the cylinder, being filled with compressed air, at the arsenal on shore, or by an air-compresser on board, to a pressure of about 500 lbs. to the square inch. The other end of the cylinder is fitted with a coupling joint, to receive a discharge pipe leading to the deck or superstructure of the boat, where it is fitted by means of a ball-and-socket joint, to a delivery tube having a nozzle of suitable internal diameter. The delivery tube rests on a stand provided with an arrangement which admits of the nozzle being turned in all directions and elevated or depressed. After the piston has been inserted in the cylinder, and the air-chamber affixed to the aft end, the cylinder is first filled with a quantity of water by means of a funnel; on the water is then poured, through the same funnel, a quantity of crude petroleum, varying from 10 to 60 gallons, according to the capacity of the cylinder, which will fill it up to the stopcock where the discharge pipe begins. The stopcock is then closed, and the liquid contained in the cylinder may be discharged at any desirable moment by the opening of the respective air and petroleum cocks on the air-chamber, cylinder, and delivery tubes. The compressed air pushes the piston forward, and the crude petroleum which falls on the object aimed at, is ignited by the enemy's own fire, or by an incendiary rocket.

The Fig. on page 97 shows a vessel similar to that just described, but fitted with spar-torpedo gear, instead of the Whitehead torpedo gear. The hollow steel spars, 45 ft. long, one on each side the vessel, slide in tubes, attached to, or rather forming part of a tail-jointed elbow piece. These have two motions; they not only swing clear of the funnel, so as to bring the spars athwart ships, but also fall down like the lid of a box, thus bringing the spar on to the surface of the water. These motions are given by wire ropes worked from the inside. The torpedo is either fired by impact or by electricity, after being placed in its desired position. The recoil generally sends back the torpedo vessel uninjured.—*Extract from "Iron."*

Thorneycroft's High Speed Torpedo Boats.—"The hulls of these torpedo boats are made of Bessemer steel galvanized: the majority, as built for the Admiralty, being fitted with upright stems, and having the stern post continued in a loop below the propeller, with a view to its protection. The hulls are divided by bulkheads and semi-bulkheads into a number of compartments so that in the event of one of them being filled the boat would still float. In the forward end of the vessel accommodation is provided for the crew, the space being fitted up with lockers, and having hammock hooks attached to the decks. Immediately aft of this cabin is the steering compartment fitted with a conning tower, in

which are arranged the telegraph gear, the voice pipe communicating with the engine room. and the starting gear for the torpedo discharging tube. Aft of the steering compartment is the boiler room with the coal bunkers fitted on either side. The stokehole is so arranged that the only exit for air blown into it is through the boiler, thus forming an arrangement of artificial draught without which it would be very difficult to get the power necessary for propelling these boats at the high speeds which have now been attained.

Separated by a bulkhead from the boiler room, is the engine room, in which the necessary pipes and machinery are very skilfully arranged within uncommonly close quarters. Accommodation for the officers is provided aft of the engine room, and is of an ample, not to say luxurious, character.

The decks of these boats are of steel, covered where foothold is necessary with Welsh's cement, and having hatchways leading to the different compartments. Those leading to the engine room, boiler room, and forward compartment being fitted with springs which throw the hatches wide open on withdrawing the fastening, and so give ample space for egress on an emergency.

The torpedo boats we are describing are armed with the 14 in. Whitehead torpedo, which is discharged through a tube mounted on a revolving carriage on the forward deck. Three torpedoes are usually carried, one in the tube, and two on transporting carriages mounted on rails on either side of the vessel, and so arranged that they can be run forward when the discharging tube is to be loaded. The impulse tube for discharging the torpedoes is attached to the cover of the after-end of the discharging tube, and consists of two pistons with hollow rods arranged telescopically, and capable, when compressed air is admitted behind them, of expelling the torpedo at a speed of 16 ft. per second.

Experiments have been made by the Admiralty with a view to finding the coal consumption of these vessels; the result being that in one vessel, at a speed of 17½ knots, the engines developing 340 horse power, the consumption was 3 96 lb. per indicated horse power per hour; in another, doing 18¾ knots, the engines developing 340 horse-power, the consumption was 3·92 lb. per indicated horse power per hour; the difference in speed between the two boats with the same horse power being due to the condition of their bottoms.

The engines are of the vertical compound intermediate receiver type, with cranks at right angles; the high and low pressure cylinders being respectively 12¾ in. and 20⅞ in. diameter, and the stroke in both cases being 12 in.; the cylinders, which are steam jacketted, are both cast in one piece with their valve chests, each cylinder being fitted with a liner; the space between which and the cylinder casting proper forms the steam jacket; the cylinder faces are double ported, and the valves are arranged to give double openings for both steam and exhaust. The cylinders are connected to the bedplate by eight vertical standards, these standards being braced together at about the middle of their height; the crossheads

have slipper guides; the valve gear is of the ordinary link motion; the reversing shaft carrying a toothed quadrant, geared into by a worm on a transverse shaft carrying the hand leavers. The air pump, which is single acting, is of unusual proportions, it being 12 in. in diameter, with 3 in. stroke. It is worked by leavers coupled to the crosshead of the low-pressure cylinder so that it works at the same number of strokes as the engines, namely, considerably over 400 double strokes per minute; this is a very high number of reciprocations for an air pump, but arranged as they make them Messrs. Thorneycroft find their pumps give no trouble; the large diameter enables a large valve area to be obtained, the arrangement of the foot, piston, and delivery valves being alike. The feed pumps are plunger pumps fixed to the bed-plate and driven from cranks formed at the ends of the cross-shaft, which carries a worm-wheel, geared into by a worm on the forward end of the crank shaft. From this cross shaft the bilge pump is also driven.

The surface condenser is cylindrical, and is distinct from the engines; the condensing water is forced through this condenser by a centrifugal pump, driven by an independent engine. The engine-room also contains another independent engine, namely, one for driving a fan situated in the stoke-hole, by means of which a supply of air is forced into the latter; this engine is coupled direct to the fan shaft, and is sometimes driven at over 900 revolutions per minute. In the engine-room is also placed an air compressing pump for supplying compressed air to the torpedoes, and to the impulse tube for discharging them. The donkey engine is fitted in the boiler room.

The engines are supplied with steam by a boiler of the locomotive type; the shell is of Bessemer steel, and the inner fire-box and tubes are of Lowmoor iron; the fire-box casing is of the Belpaire pattern, its top being stayed direct to the crown of the fire-box. The boiler contains 204 tubes $1\frac{3}{4}$ in. in diameter, the total heating surface being 618 sq. ft., of which 57 sq. ft. is fire-box surface, and 561 sq. ft. external tube surface. The fire-grate area is 18 sq. ft., the fire-bars not extending the whole length of the fire-box, there being a transverse brick bridge a short distance from the tube plate. The flue area through the tubes (disregarding the ferrules at the fire-box end) is 2.7 square feet, or $\frac{1}{6.6}$ of the grate area.

The boiler is fitted with a patent apparatus for preventing accidents to the people in the stoke-hole, in the event of any of the tubes giving out while the boiler is under steam; this arrangement consists of a series of wrought iron flaps hinged to the front of the ash-pan, in such a way that they will be closed by any excess of pressure within the ash-pan; while, in order to prevent the ash-pan being damaged by an excessive pressure, a passage is formed at one side leading up to the deck, and fitted with a door with a spring fastening, so arranged that the door may be blown open by a comparatively slight pressure from within. The steam, &c., from the ash-pan would thus escape into the air, and the people in the stoke-hole would be safe, inasmuch as the stoke-hole is closed, the air

being forced into it to produce the necessary draught through the boiler. An arrangement of the kind just described is most essential for safe working.

Of the performances of Messrs. Thorneycroft & Co's. first class torpedo boats, the engines at the full power trials have been found to indicate 469 horse-power at 433 revolutions per minute, this being at the rate of a horse-power for every 1.35 sq. ft. of total heating surface. Also that at a speed of 18¾ knots, the engines have been found to develope 340 horse-power with a consumption of 3.92 lbs. per horse-power per hour. The quantity of coal consumed per hour in this case would thus be $340 \times 3.92 = 1332.8$ lb."—*Extract from "Engineering"*

The Torpedo Boat of Messrs. Yarrow & Co.—"Some interesting advances in the arrangements of vessels designed for carrying on torpedo warfare have recently been effected by Messrs. Yarrow and Co., of Poplar, in a torpedo boat of the first class which they have built for a foreign Government. The alterations have a twofold character, and have reference to the arrangements for discharging the products of combustion from the furnaces and to those for steering the vessel. In brief, the boat is funnel-less and is fitted with two rudders, one at each end. The main object in dispensing with the funnel is to enable the torpedo boat to approach as closely as possible to an enemy without being seen, a secondary, although still an important consideration, being the absence of any obstruction to the steersman's view, such as a funnel on the deck forms. The outlets for the smoke in the present instance are two ports, one on either side of the vessel, and placed about 15 ft. in from the bow. Each of these smoke ports is fitted with a damper, and the smoke can be turned through either or both of the passages as desired. The control of these dampers is given to the steersman, who, on approaching an enemy, can direct the products of combustion through the port on the unexposed side of the vessel. The emission of smoke by day and of the glare and sparks by night, are thus to a very large extent hidden from view, enabling the torpedo boat to approach very closely to the point of attack without being observed. The outlets are fitted with valves which are kept open by the blast, but which close on being struck by a passing wave. Should the vessel have to be out when a heavy sea is running the ports are closed, and a spare funnel is rigged up on deck, on one side. Although the smoke ports are placed forward in this boat it is intended to place them aft in the next that Messrs. Yarrow build, as that arrangement will obviate the inconvenience at present experienced by those on deck from the heated gases of the furnace being carried along it at times by the wind, when on a certain course.

The steering powers of the boat have next had attention from Messrs. Yarrow, and they have sought to remedy the defective steering common to these large quick-speed torpedo craft. To do this they have fitted the vessel under notice with two balanced rudders, one of which is placed forward about 10 ft. from the bow, and the other in its usual position at

the stern with the screw abaft it. Both rudders are connected with the same steering gear, and are operated simultaneously by one steersman. The forward rudder can be be raised out of the water into a casing inside the boat if desired, by means of a screw cut on the upper part of its spindle. By the same means, by unscrewing the collar on the spindle, the rudder can be released and dropped into the water should the necessity arise for so doing, by reason of its becoming fouled or damaged. In trials which have been made with this double-steering system, it has been found that when steaming at high speeds the forward rudder has a much greater control over the motion of the boat than the stern one. The reason assigned for this is that at high speeds the forward part of the boat is lifted out of the water, and consequently offers a diminished side resistance to any turning motion brought to bear upon it.

The boat in which these improvements have been introduced is 86 ft. long by 11 ft. beam and 5 ft. 6 in. deep. She is fitted with compound engines having 22 in. and 12½ in. cylinders, with a 12 in. stroke, and making 520 revolutions per minute when running at full speed. She is propelled by a three-bladed screw 5 ft. 6 in. in diameter and 5 ft. pitch. She made a trial run, upon which occasion several gentlemen interested in torpedo warfare were present. Although not tried for speed she was estimated to run at 16 knots an hour with easy running. Put through some revolutions with the view of testing her steering powers, the double rudder arrangement was found to answer exceedingly well, and she turned a circle of a diameter equal to about three times her own length in 1 minute 15 seconds. She turned equally well with either rudder, and in fact her steering capabilities were satisfactorily demonstrated. The new arrangement for carrying off the smoke also answered very well, with the exception that the heated gases occasionally swept the deck, which objectionable result will be avoided in future boats, as we have already stated."—*Extract from "Engineering."*

Messrs. Yarrow adopt supplementary engines for driving the air pump, circulating pump and feed pumps ; they consider this plan preferable to that of working these pumps direct off the main engine, as is sometimes done. One advantage in having separate pumping engines is that, whether the vessel is in motion or stationary, a powerful means is available for pumping her out, should the necessity arise. It is estimated by her builders that if the air pump and circulating pump were both utilized for this purpose the water could be pumped out as fast as it could enter either of these vessels through 100 holes made in the skin by Martini-Henry rifle bullets. If this is the case, these craft may be deemed safe from sinking so long as their machinery is working efficiently. The boiler of the locomotive type, is placed in the forward part of each vessel, and has a closed stoke-hole. In connection with the boiler a very important improvement has been introduced by Messrs. Yarrow. This consists in a means of rendering the closed stoke-hole safe for the men in the event of the collapse of a boiler tube—a contingency which cannot be absolutely guarded against.

The Highest Speed Ever yet Attained.—At a trial which took place at Long Reach in March, 1879, of a first-class torpedo boat constructed by Messrs. Yarrow and Co., of Poplar, for the Admiralty, three runs were made with the tide and three against it, in the usual way, with the following results :—

Runs.	Time, Min. Sec.	Knots per hour.		Knots per hour.
First	2 37 =	22. 93	Mean of first pair =	21. 35
Second	3 2 =	19. 78		
Third	2 33 =	23. 53	Mean of second pair =	22. 05
Fourth.....	2 55 =	20. 57		
Fifth	2 30 =	24. 00	Mean of third pair =	22 23
Sixth	2 56 =	20. 45		

Mean of means, calculated by the Admiralty method, 21. 93 knots, which is equal to 25¼ statute miles. The load carried during the trial was 6¾ tons, which represents the weight of torpedoes, gear, coals, &c. The steam pressure was 124 lbs. throughout, and during the four first runs the engines were slightly eased, which accounts for the last pair of runs giving the best result. It was found that at speeds of between 17 and 19 knots the vibration of the boat was considerable, but when running over 20 knots it entirely disappeared, so much so, in fact, that it was quite possible to write legibly on the stern immediately over the screw. This craft was of precisely the same dimensions as those built for the English Government, which on their trials have given speeds varying from 18 to 19 knots ; and this little steamer, which is only 86 feet long, stands unrivalled as the fastest vessel in the world.

To Find the Number of Passengers a Launch will carry in smooth water.—Multiply the length of the boat by the beam and divide by six ; the result will be the number of persons to carry.

Vibration and Speed.—It is the vibration in lightly built steel boats that practically limits their speeds, by determining the strength and weight of their construction ; the lighter they are the greater will be their speed, but the vibration will also be greater.

Life Buoys.—"No life buoy, stuffed with rushes or with cork shavings, or other shavings, or granulated cork, or any loose material should be passed. All cork life buoys should be built of solid cork, and fitted with life lines and loops securely fixed to the life buoy, and none should be passed that will not float for 24 hours in water with 32 lbs. of iron suspended from them. If life buoys are not made of solid cork, then any other strong life buoy of an approved pattern may be passed, that is capable of floating in the water for 24 hours with 40 lbs. of iron suspended from it. No contrivance is to be passed as a life buoy that requires inflation before use."

Life Jackets.—"No life jacket or belt should be passed that is not capable of floating in the water 24 hours with 23 lbs. of iron suspended from it; and to insure this buoyancy a life jacket, in which the cork must be exposed, and have a canvas back and straps only, should weigh 5 lbs. when dry."

COMPLETE WORKING SPECIFICATION OF SMALL TWIN SCREW VESSEL.

Length between perpendiculars	65 ft.
Breadth extreme	15 „
Depth moulded	8 „ 2 in.

Keel.—To be of best hammered scrap-iron 4 in. × $\frac{3}{4}$ in. with scarphs 12 in. long, closely fitted and well rivetted together, and of the greatest lengths procurable.

Stem.—To be of best hammered scrap-iron 4 in. × 1 in. to be properly scarphed to the keel and well rivetted thereto.

Stern Post.—To be of best hammered scrap-iron 4 in. by 1 in. properly scarphed to the keel, and well rivetted thereto. Braces for the rudder pintles are to be forged on the post solid.

Middle Line Keelson.—To be formed of two angle-irons $2\frac{1}{2}$ × $2\frac{1}{2}$ × $\frac{1}{4}$ in. worked back to back, and secured to the reverse angle-irons on the floor plates, and to short pieces of angle-iron on the floors. These angle-irons are to be worked continously, and their butts are to be efficiently strapped.

Frames.—To be of angle-iron 2 in. × 2 in. × $\frac{1}{4}$ in. spaced 21 in. apart throughout the length of the vessel, each frame to be in one length from stringer to stringer.

Reverse Frames.—Of angle-iron $1\frac{3}{4}$ in. × $1\frac{3}{4}$ in. × $\frac{7}{16}$ in. worked on every floor from upper turn of bilge to upper turn of bilge. On every alternate frame the reverse angle-irons are to extend from stringer to stringer and are to be in one piece; the reverse bars under the engines to be doubled.

Floors.—The floor plates to be worked on every frame to be $\frac{1}{4}$ in. thick, 8 in. deep at the middle, extending from bilge to bilge in one piece. Holes for water courses are to be cut in the floors.

Engine and boiler bearers, to be as required by the engines.

Outside Plating.—In arranging the butts, care is to be taken in all cases, that there are two plates between butts placed vertically over each other. The thickness of the plating to be as follows; from keel to upper turn of bilges $\frac{1}{4}$ in.; from upper turn of bilge to sheer strakes $\frac{7}{16}$ in.; sheer strakes $\frac{7}{16}$ in.; topside plating $\frac{5}{16}$ in. Plating in wake of supports to shaft tubes and shaft to be increased in thickness or doubled, as may be directed. Every alternate strake to be fitted close on the frames, the remainder to be

fitted wholly outside them; the spaces between the outside plates and the frames to be filled in with liners of the same thickness as the adjacent plates. The liners in wake of the water-tight bulkheads to extend on each side of the frame angle-iron, so as to take two additional rows of rivets on each side.

The plating ending on the stem and stern post to be double rivetted, the laps to be single rivetted, and the butts to be double chain rivetted. The breadth of the butt straps to be $11\frac{1}{2}$ times the diameter of the rivets. The butt straps of all plating to have the fibre of the iron in the same direction as the plates, and those on the inner plates, to extend the whole breadth of the plates, and those on the outer plates to be carefully fitted between the edges of the inner plates.

All butt straps and faying surfaces of the plates to be cleaned from rust before being worked. The plates to be truly fitted at the edges and butts, and all the joints caulked in the most careful manner. No canvas, red lead, paint or other substance on any account to be inserted in the seams, but to be caulked throughout metal to metal.

All butt straps to be cut off from plates of the same strength as the plates they are to connect.

The punching and counter-sinking of the holes to be carefully done, and the holes to be rimed out wherever required.

The spacing of the rivets connecting the bulkheads with the bottom, to be as open as is consistent with water-tightness.

The top side plating to be properly fastened to the sheer strake, and to be stiffened at every alternate frame by an angle-iron 2 in. × 2 in × $\frac{1}{4}$ in., which should step on and be fastened to the stringer plate. Freeing scuttles to be fitted in this plating, hinged and secured with drawbolts.

Transverse Water-tight Bulkheads.—Placed as will be shown on the drawings, and to be bounded by the outside plating and upper deck. The plates for all the bulkheads to be $\frac{7}{16}$ in. thick, except the plates in wake of stuffing boxes which are to be $\frac{1}{2}$ in. thick, to be lap-jointed, single riveted, and supported with angle-irons 2 in. × 2 in. × $\frac{1}{4}$ in., placed vertically 2 ft. 6 in. apart. The bulkheads are to have single angle-irons $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{1}{4}$ in. on the upper part, for connection with the upper deck, and single angle-irons 2 in. × 2 in. × $\frac{1}{4}$ in. on the outer edges, for connection with the bottom plating; suitable angle-irons to be fitted for connection with the fore and after cabin flats, and the whole work to be carefully caulked and made water-tight.

A water-tight manhole with cover to be fitted in the foremost bulkhead.

A sluice valve or cock to be fitted to each water-tight compartment, with levers and rods for opening and shutting them, such rods to pass through stuffing boxes where required. The sluice valves are to be worked from the upper deck, and the rods where connected together to have metal bolts. Means are to be taken for indicating on the upper deck whether the sluice valves are open or shut.

Holes in Bulkheads.—Holes in bulkheads for pipes to be made good with stuffing boxes.

Stringer Plates.—To be 12 in. wide, $\frac{1}{4}$ in. thick, securely fastened to the sheer strakes by means of longitudinal angle-irons, $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{1}{4}$ in. They are to be well riveted to the ends of the beams, and the butts to be well strapped, and give good shift with butts of sheer strake, &c. From the stem to station 3, the plating is to extend right across the deck.

Tie Plates.—To be 6 in. × $\frac{1}{4}$ in., and to extend the whole length of the vessel. The butts to be efficiently strapped, and the plates securely riveted to the beams. If necessary an additional tie plate to be worked on each side, in wake of the engines and boilers.

Beams, Half-Beams and Carlings.—The upper deck to be of angle-iron, 3 in. × $2\frac{1}{2}$ in. × $\frac{5}{16}$, well secured to the frames. The half-beams and carlings to the upper deck to be of the same depth and section as the beams, where considered necessary; but are generally reduced in dimensions as may be directed. The knees on the half-beams to be generally reduced in size.

Carlings, wood or iron, between the beams, to be fitted as may be directed.

The beams to platforms to be of angle-iron, 2 in. × 2 in. × $\frac{1}{4}$ in. The whole of the beams to be in one length.

Pillars.—Solid iron pillars, $1\frac{3}{4}$ ins. diameter, to be fitted to every upper deck beam.

Coal Bunkers.—Formed of plates $\frac{1}{8}$ ins. thick, stiffened with angle-irons, 2 in. × 2 in. × $\frac{1}{4}$ in., placed vertically 30 in. apart. To be complete with coaling scuttles in deck.

Upper and Lower Deck Flats.—The upper deck flat to be of Dantzic crown deals, $2\frac{1}{2}$ in. thick, except the water-ways, strakes in wake of hatches, windlass, &c., which are to be of teak. The lower deck flats to be of Dantzic crown deals, $1\frac{1}{2}$ in. thick. The material for the deck flats to be well seasoned, free from knots and other defects.

The deck flats to be secured to the beams with galvanized iron screw bolts and nuts; to be planed on all their surfaces, and such part of them as may be in contact with iron, to be thickly coated with red lead or other approved material. The butts are to be on the beams, and supported by, and fastened to pieces of plate attached to the beams, or short pieces of reverse iron. The deck flats to be well caulked with oakum and made water-tight, and the seams payed with pitch.

Coamings.—The coamings and headledges to be of teak, 3 in. thick, efficiently secured to the beams and carlings.

Skylights and Companions.—To be of mahogany or teak, glazed with plate glass, and fitted with sliding sashes, brass guards, &c.

Gratings, &c.—All necessary gratings, deadlights and cap-scuttles, to be fitted. Iron gratings to be galvanized where required.

Ladders.—Where necessary, and of a suitable description, fitted with backs if required.

Rough Tree Rail.—To be of teak, 6 in. wide, 2 in. thick, secured to an angle-iron, $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in × $\frac{5}{16}$ in, worked on the topside plating.

Hawse Pipes, Stern Pipes, &c.—To be fitted with the necessary chocks of suitable sizes.

Towing and Lashing Bollards, &c.—Four pairs of cast-iron bollards to be fitted and firmly secured in their proper places. A wooden bollard to be fitted aft.

Chain Locker.—To be formed underneath the lower deck flat, just before the boiler room bulkhead, provision to be made for securing the clench of the cable. On the upper deck, on one side only over the chain locker, a small deck pipe to be fitted.

Scuppers.—Iron scuppers, $3\frac{1}{2}$ in. × 2 in., in the clear, two on each side; they are to be flanged on the deck, also on the outside, and fitted with a guard.

Boat's Davits.—To be fitted complete with all guys, cleats, &c., crutches and other supports, chain and appliances for raising, lowering, stowing, and securing the boat, including blocks and falls. The davits to be arranged so as to admit of the davits with the boat attached being turned in-board.

Engine Room Telegraph.—To be fitted as required.

Cabins.—To be built complete, with all bed places, cots, drawers, tables, lockers, wash and other stands, hat and coat pegs, shelves and other fittings, in a first-class manner. The iron plating overhead to be covered with an approved composition.

Fittings for the Crew.—To be fitted complete as may be necessary for berthing and messing the ship's company.

Cabin and Forecastle Stoves.—To be supplied.

Bow and Anchor Lights.—Of an approved pattern.

Circular Side Lights.—Of an approved plan, 6 in. diameter, and disposed as directed.

Fittings for Engineers' Stores.—To be provided in the engine room, complete with all necessary tanks, with bars and locks; for oil, tallow, &c.; drawers, cupboards, and vice-bench as usually fitted.

Fittings to be Stowed.—All fittings such as hatchway covers, scuttles, &c., to be stowed.

Tumbler and Clasp to Ensign Staff, to be fitted.

Stays to Funnel.—Funnel to be properly stayed.

Ship's Bell.—To be fitted of a suitable size and pattern, with ship's name engraved thereon.

Locks and Keys.—Locks, keys, and other fastenings to be provided and fitted complete. All keys to have brass tallies, with distinguishing marks attached to them.

Ring and Eye Bolts.—To be fitted wherever required.

Binnacle and Compass.—The compass and stand to be supplied and fitted in place, including adjustment.

Water Cask.—Capable of holding 18 gallons to be provided and fitted with a stand against the side, just before the after locker on upper deck.

Pumps.—Two flush deck pumps, one forward and one aft, to be provided, with all necessary fittings.

Belaying Cleats.—Belaying cleats 9 in. long, $\frac{5}{8}$ in. diameter, to be fitted to the top sides throughout the length of the vessel on both sides, and in the gunwale corresponding iron belaying pins to be fitted.

Chart House, &c.—To be fitted complete, with glazed sashes, stanchions, &c.

An approved form of w.c. covered with canvas, to be fitted; also opposite to this a locker for the stowage of stores.

Rubbing Pieces.—Of elm, 5 in. × 4 in., neatly rounded, and protected by iron bands securely connected to the sides.

Rudder.—To be made of the best hammered scrap-iron. The head 2 ins. in diameter, and the pintles forged solid on the frame. The steering arrangements, consisting of rods and chains leading from wheel; tiller, spare tiller, hand tiller, blocks, steering wheel, &c., to be supplied and fitted.

Shaft Tubes.—Two wrought-iron tubes, one under each quarter, to be formed for enclosing the propeller shafts; the fore part where they leave the run of the vessel to be supported by the framework of the vessel, which is to be bossed out in a suitable form for the purpose, and the after part supported by struts.

Bilge Keels.—Bilge keels formed of bulb iron $\frac{3}{8}$ in. thick 6 in. broad, and about 25 ft. in length, to be fitted as shown. They are to be connected to the bottom plating by double angle-irons 2 in. × 2 in. × $\frac{1}{4}$ in.

The traces of the planes of the bilge keels, on the middle longitudinal plane, are to be parallel to the plane of the water line.

Outfit.—The following outfit to be provided with the vessel;—

1 Warp, 6 ins., 60 fathoms.
1 „ 5 „ „
1 „ 4 „ „
1 Heaving line, $1\frac{1}{2}$ in.
1 Flagstaff.
1 Ensign.
1 Long hitcher.
1 Hand lead and line.
2 Cork fenders.
2 Coir mats for cabin stairs.
1 Set lanterns, viz.: port, starboard, masthead and anchor lamps.
3 Oak buckets.
2 Mops.
2 Deck brooms.
2 „ scrubbers.
1 Life buoy.
1 Compass in box.
1 Draw bucket.
1 Anchor, 3 cwt. (stock included), and 60 fathoms of $\frac{5}{8}$ in. chain.

General Fastenings and Qualities of Materials.—All rivets to be of iron, approved by the Inspector to look after the vessel while under construction. The breadths of butt straps, &c., where not specified, and the size, form and pitch of rivets, to be as directed by the Inspector. The

riveting to be executed in a careful and workmanlike manner, the rivets thoroughly fitting the holes, and the greatest care to be taken in punching to prevent unfair holes, all such holes to be rimed out before riveting. All counter sinking and riveting to be completed as required by the Inspector.

The after plates in the vicinity of the screw shafts, where the bend or flange is considerable, and there only, to be of Lowmoor or Bowling iron. The skin plating from the keel to the upper deck, and the stringer and tie-plates, to be of "Best-Best" plate; the remaining portion of the plates to be of "Best" plate, unless otherwise specified.

The plates to have the maker's distinguishing mark stamped legibly upon each plate.

The Inspector will test the strength and durability of the iron; should the samples tested fail to stand the test, or prove otherwise defective, or of inferior quality, the lot from which the sample may be selected may be rejected.

Testing Forged Work.—The securities for receiving the clench of the cable, all shackle ring and eye bolts, stopper bolts and slips, all blocks, including eyes or hooks for boat's davits, and such forged work, on the efficiency of which the safety of the vessel, or of life, directly depend, will be tested.

Testing Water-tight Work.—All water-tight work to be tested by filling the compartments with water, and where defects are discovered, they are to be made good, and the compartment re-tested till found perfect.

Clearing Bilges.—Chips, &c., to be cleared out of bilges and every compartment before being delivered up by the builder.

Painting.—All ironwork to be scraped and cleaned before being painted, and each portion of it, as it is turned out of hand, is to have a coat of thin red-lead paint, as soon as it is sufficiently completed to receive it, in order to prevent as far as possible the iron from becoming oxidised.

In addition to the foregoing, the whole of the ironwork of the vessel, both inside and outside, is to be covered with three coats of the best oil paint, or an approved composition may be substituted as and where directed. The outside of the bottom plating, instead of red-lead, to be coated with four thick coats of protective varnish or approved composition. All woodwork to be painted in the best manner with three coats of the best oil paint, of such colour and with such portions grained and varnished, or varnished only, as the Inspector may direct. All mahogany, teak doors or fittings to be French polished as directed.

Cement on the Inside of Bottom.—Cement to be used as high as the limber holes, and extending to the upper turn of the bilges. The plating to be painted where required before the cement is put on.

Galvanizing Work.—All iron fittings exposed to the weather to be galvanized.

Quality of Material and Workmanship.—The whole of the materials and workmanship to be of the very best quality, and all woodwork to be well seasoned. All work to be finished to the satisfaction of the Inspector.

Tracings.—The builder to supply any tracings of details which the Inspector may deem necessary to submit for approval, before proceeding with the work. Also, the Inspector to have access to the drawings of the vessel during the progress of building.

Completion.—This contract is intended to include the entire completion of the vessel ready for sea. It is therefore to be expressly understood, that all minor fittings which may not be shown on the drawings nor mentioned in this specification, but requisite for the proper completion of the work, are to be provided without additional charge. Also, if it should turn out desirable to omit some of the work herein described, or to perform them in a less costly manner, any expense of material or labour thus saved, is to be placed to the credit of the vessel as a set off against any extra work which may require to be performed.

Patent Rights.—The contractor to be responsible for the payment of all Patent Rights or Royalties that may be used or infringed, in the fitting of the vessel.

The vessel, when launched and completed, to be delivered, in a safe berth or moorings, over to the owner or those appointed by him to receive her. Any responsibility to remain with the builder till then.

SPECIFICATION OF ENGINES.

Particulars for the construction of a set of Inverted Engines, of 110 Collective Indicated Horse-Power, with Twin Screws.

Engines.—Each screw to be driven by an independent pair of engines with vertical inverted cylinders, of the collective indicated power of 110 horses. This power to be guaranteed by the contractors on the measured mile.

Cylinders.—The diameter of the cylinders to be 11 in., with 11 in. stroke, and the number of revolutions to be about 180 per minute. Suitable apparatus to be provided for taking indicator diagrams from each end of the cylinders. Cocks with pipes leading into the bilge, for draining water from both of the cylinders, and slide jackets to be fitted. The cylinders to be supported on one side by standards cast on the condenser, and on the other side by malleable iron columns.

Slide Valves.—To be made of hard close-grained cast iron, scraped up to a true surface. The slide valves to be single ported, and fitted with packing rings on the back to relieve them of part of the steam pressure. The slide valves to be worked by link motion, and means to be provided for fixing the links in any position, the links to be of wrought iron, and the valve rods of cast steel. All the working parts of the valve motion to be made of steel. The slide valves to be fitted with efficient means for lubrication, both when the engines are at work and when cold.

Clothing of Cylinders.—The cylinders and their covers, valve casing and covers, and all hot surfaces, to be covered with hair felt and wood, secured with polished brass straps.

Pistons.—To be of approved construction, fitted with a single packing ring, held out by well tempered steel springs, or by Ramsbottom rings.

Piston Rods.—To be of steel, 2 in. diameter, the piston rod glands to be single, and deep cone rings to be fitted at the bottom of the stuffing boxes. The surfaces of the piston rod guides to be as large as possible, and the guides to be so fitted as to be capable of adjustment.

Connecting Rods.—To be of best forged scrap iron, 2 in. diameter, and the bearings at the crank end to be of phosphor bronze.

Crank Shafts.—To be made of the best forged scrap iron, $3\frac{3}{8}$ ins. diameter, the aggregate length of the bearings to be not less than 1 ft. 9 in. The diameter of the crank pins to be the same as that of the bearings, and their length to be not less than their diameter. The crank shaft bearings to be of phosphor bronze.

Propeller Shafting.—To be of the best forged scrap iron, and to have solid couplings. The diameter of the intermediate shafts to be 3 in., and the stern shaft $3\frac{3}{8}$ ins., exclusive of the brass casing.

Turning Gear.—To be provided for turning the engines by hand.

Stern Tubes.—The driving shaft within the tubes, to be wholly cased with gun-metal. A pipe and cock to be fitted for drawing water from each stern tube. Lignum-vitæ, or vulcanite to be used for the bearings at each end of the tubes.

Screw Propellers,—To be 4 ft. 6 in. in diameter, they having to work outwards.

Surface Condensers.—Each pair of engines to have a separate surface condenser with 116 brass tubes $\frac{3}{4}$ inch diameter, and 3 ft. 9 in. long between tube plates, giving a cooling surface of 85 square feet. The condensers to be so constructed as to be capable of working as common condensers, and arranged so that the tubes can be readily packed at each end, and be taken out without removing any part of the engines. Holes are to be provided, to admit of the interior of the condensers and the condition of the tubes being examined, and of the deposit being cleaned out from all parts. A cock to be fitted for the purpose of clearing each condenser of the circulating water when the engines are stopped. Provision to be made for cleaning the condensers by hot water from the boilers, and a permeator of suitable size and description to be fitted in front of the tube plate, for the purpose of admitting an alkaline solution into the exhaust passages. The tubes to be brass, No. 18 wire gauge in thickness, and tinned inside and out, as well as annealed. The tube plates to be of brass. The tubes to be secured to the plates by tape packing and screwed glands, and the circulating water to be outside of the tubes. The condenser must be capable of maintaining on the trial, a vacuum of within three inches of the barometer.

Air Pumps.—Each air pump to be $7\frac{3}{4}$ inches diameter and 7 inches stroke, to be lined with gun-metal $\frac{3}{8}$ inch in thickness. The bucket, also

foot and discharge valve, and rod, to be of gun-metal; the valves of India-rubber.

Circulating Pump.—A centrifugal pump to be fitted in the vessel, driven by an independent engine, to circulate the cold water through both condensers, and to be connected to the bilge, by a cock and non-return valve, in place of the ordinary bilge injection cock, to draw water from the bilge in the event of a leak in the ship, and so fitted that the necessary connection can be readily made from the engine platforms.

Feed and Bilge Pumps.—Each pair of engines to be fitted with a feed pump, and a corresponding bilge pump of the same size, worked from the piston rod cross heads; of 1⅝ diameter and 11 ins. stroke; each feed pump to be capable of supplying the boiler with the quantity of water necessary to produce steam for both pairs of engines; stop cocks to be fitted to the suction pipes of these pumps. Pressure gauges to be fitted on the feed pipes, ranging up to twice the boiler pressure; all valves to be of gun-metal; feed pipes to be 2 in. diameter.

Auxiliary Engines.—An auxiliary engine to be fitted in the boiler room, adapted to work either by steam or by hand; the cylinder to be 5 ins. diameter, the stroke 5 ins.: and the pump 2½ ins. diameter. This pump to be capable of supplying the boiler with the requisite quantity of water when working full power; to draw water from the sea only. A second auxiliary engine and pump, adapted to be worked either by steam or by hand, to be supplied, and fitted in the engine room as a fire engine, and for washing decks and pumping out the bilge and boiler; it should draw water from all compartments and from the sea. The steam cylinder to be 8 ins. diameter and 8 ins. stroke; and the pump to be 4 ins. diameter and 8 ins. stroke, double acting. The discharge pipe from the pump to be fitted with nozzles on deck, and stop cocks as required for use, in case of fire; and to have separate suction and discharge pipes from those of the main engines. All pumps worked by the engines, also all auxiliary steam pumps to be fitted with escape valves; non-return valves also to be fitted to guard against the danger arising from leaving open the sea cocks. Escape valves to be placed easy of access, and so constructed that the valves and springs can be adjusted from the outside.

Pipes.—The steam and all other pipes, to be of copper or brass, except where otherwise specified; all feed, bilge, and blow-off pipes to be of solid drawn copper; all nozzles which pass through the ships side or bottom, and the sea-suction gratings to be of gun-metal; the lower end of each bilge suction pipe to be of galvanized iron, and proper strainers of galvanized iron to be fitted to prevent choking. Care should be taken that no copper or brass pipes in the bilge, rest in contact with the iron work of the vessel; all such pipes exposed to the action of the bilge water are to be well painted or varnished, and then covered with waterproof canvas. The diameter of the respective pipes to be; for main steam pipe for each pair of engines 3½ ins. diameter; feed pipe, 2 ins. diameter; injection pipe, 2 ins. diameter; blow-off pipe, 2 ins. diameter; discharge pipes, 3½ ins. diameter, &c.

The thickness of the several pipes to be as follows :—

	Wire Gauge.
Main, and branch steam pipes	No. 6
Waste water pipes	„ 8
Bilge pipes	„ 8
Blow-off pipes	„ 6
Main, and donkey feed delivery pipes ...	„ 6
Injection pipes	„ 10
Exhaust pipe of main engines	„ 10
Main and donkey feed suction pipes... ...	„ 10
Waste steam pipes	„ 11
Exhaust pipes of auxiliary engines	„ 11
Internal steam pipes	„ 14

All bends and T-pieces, to be respectively one gauge thicker than the plain pipes.

Expansion Joints.—To be fitted to the steam pipes, and to any other pipes where they may be considered necessary, and approved means to be adopted to prevent fracture by the contraction or expansion of any other parts of the machinery, or by the working of the ship.

Clothing of Pipes.—All the steam pipes to be clothed with felt and canvas as deep as the flanges.

Regulating Valves.—In the steam pipe leading to each pair of engines, a screw down stop valve to be fitted. These valves to be conveniently fitted to admit of their being used instead of throttle valves, to regulate the steam supply to the engines.

Separator.—A separator, made of copper or brass, to be fitted to each main steam pipe. The separator to discharge into the sea ; the discharge pipe to be fitted with a stop cock and non-return valve. A glass gauge also to be fitted.

Stop Valves, and Kingston Valves.—Efficient self-acting stop valves to be fitted at the ship's side to the waste water pipes, and non-return valves to be fitted to the ends of all pipes discharging into them. Kingston valves, with the spindles cast on, and furnished with stop cocks or valves, are to be fitted close to the skin of the ship, to the blow-off pipes, and the suction of the circulating pump. All Kingstons are to be proved by a tensile strain of half a ton to the square inch of area of the valve, but in no case need the test exceed twelve tons. All valves and cocks in connection with the boilers or skin of the ship to have spigots passing through the plates. The auxiliary pumps to draw from the circulating pump Kingston.

Save-alls.—Save-alls to be fitted, for all the working parts of the engines, and for the bearings of the screw shafting ; to receive the waste oil.

Parts to be Proved by Water Pressure.—All the cylinders, pipes, and slide valve casings as far as the eduction pipes, and the auxiliary engines are to be tested by hydraulic pressure to 120 lbs. on the square inch ; the condensers, hot wells, and all remaining parts to 30 lbs. The boiler and condenser tubes to be tested by water pressure to 300 lbs. on the square inch.

Boiler.—The boiler to be cylindrical, with horizontal tubes; capable of carrying steam of 60 lbs. per square inch, and to be proved by water pressure to 120 lbs. per square inch. The boiler to be 7 ft. 8 ins. in diameter, and 7 ft. 6 ins. long, with one furnace 3 ft. 4 ins. diameter; and to have 50 brass tubes and 14 wrought iron stay tubes 3 ins. outside diameter, and 5 ft. 3 in. long between the tube plates. The boiler to be efficiently stayed to stand the working pressure.

Tube and Fire Grate Surfaces.—The area of the fire grate to be not less than 0·17 square foot per I.H.P., or about 18 square feet. The area of the tube surface between the tube plates to be not less than 2.30 square feet per I.H P., or about 260 square feet total.

General Fittings &c.—The boiler to be bedded in putty as far as requisite. The furnace door to be made so that it can be kept open in a seaway. The boiler to be fitted with a damper, two pressure gauges, two safety valves, and two internal steam pipes to obviate the effects of priming. These pipes to be of brass and extending the whole length of the boiler, and having narrow transverse slits, through which the steam must pass. A damper to be fitted to the front of the ash-pit, and external plates to the fronts of the smoke-box doors. Glass water gauges to be fitted with lamps, and gauge cocks. Blast pipe to funnel, and a fog whistle; also internal brass feed pipes arranged to promote the circulation of water in the boiler. The bottom part of the glass water gauges to be connected to the lower part of the boiler. In the boiler, zinc blocks are to be suspended, for the purpose of preventing corrosion; also circulating plates as may be considered necessary.

Boiler Plates.—The furnace, the tube plates, and the fire-box, with the angle-iron and rivets in these parts, to be of Lowmoor, Bowling, or Farnley iron, and all other parts of B B Staffordshire, or other approved iron of equal quality, the minimum thickness of the plates to be as follows :—Back and front tube plates $\frac{5}{8}$ inch, shell $\frac{9}{16}$ inch, furnaces and all other parts $\frac{1}{2}$ inch. The plates of the shells of the boilers to be double riveted in the longitudinal seams. The furnace and bearing bars to be of wrought iron.

Tests.—All plates with the exception of Lowmoor, Bowling, or Farnley Plates, must be capable of standing the following tests :—

Tensile strain per square inch,

Lengthways	...	...	21 tons.
Crossways	...	...	18 „

Forge Test (Hot).

Plates to admit of being bent hot, without fracture, to the following angles—

Lengthways of the grain	...	125 degrees.
Across „	...	100 „

Forge Test (Cold).

Plates to admit of being bent cold, without fracture to the following angles—

With the Grain,

$\frac{9}{16}$ and $\frac{1}{2}$ inch plates to an angle of 35 degrees.

Across the Grain,

$\frac{9}{16}$ and $\frac{1}{2}$ inch plates to an angle of 15 degrees.

Boiler Tubes.—The tubes (except the stay tubes which are to be of wrought iron, Lowmoor, Bowling, or Farnley), are to be of brass, solid drawn. They must contain not less than 68 per cent. of best selected copper, and be capable of standing the tests required. They are to be 3 inches diameter, No. 9 wire gauge mean thickness, and about $1\frac{1}{8}$ ins. apart horizontally.

Manholes.—In the manufacture of the boiler, care to be taken to leave sufficient room for manholes at the upper and lower parts, for the purpose of cleaning and repairing. All manholes and mudholes to be fitted with stiffening rings. The manhole and mudhole doors to be of wrought iron, and to be placed on the inside of the boiler. The manhole on the top of the boiler to be raised to clear the lagging.

Stays.—The stays to be arranged so as to admit of easy access to the internal parts of the boiler.

Blow-off Cocks.—Surface blow-off apparatus as well as bottom blow-off cock to be fitted to the boiler.

Safety Valves.—The safety valves to be loaded with springs, and to have means of easing them. They are to be connected to the boiler independently of the inside steam pipe. The condensed water from the safety valves to be delivered into a tank in the engine room.

Boiler Mountings.—The feed and blow-off cocks, stop and safety valves, and the boiler mountings generally to be of gun-metal, any internal apparatus for working the safety valves, to be bushed with gun-metal at the joints and glands, to prevent its rusting and sticking; all pipes inside the boiler to be of brass.

Clothing of the Boiler.—After the boiler has been proved it is to be well painted with red lead; and afterwards clothed with four thicknesses of boiler felt covered with galvanized sheet iron $\frac{1}{16}$ inch thick. The parts of the boiler within two feet of the uptake or funnel are not to be covered with felt, but with a non-combustible mastic or cement.

Stoke-hole Floor Plates.—The stoke-hole floor plates to be of wrought-iron ribbed, not less than $\frac{5}{16}$ inch in thickness.

Funnel.—The height of the funnel to be 21 feet from top of fire-bars; all necessary air casings and screens for ventilation to be fitted; also ventilator tubes of 15 to 20 inches diameter, with cowls on top, these tubes to be also fitted for hoisting ashes, An iron cover for the top of the funnel to be supplied.

Store Tanks.—Tanks to hold the required quantity of oil, tallow, paint, oakum, indiarubber valves, and other engineers stores, with necessary means

of securing them to be provided. To be fitted in the engineer's store room and engine room, as may be required, with brackets, straps, and locks.

General Fittings.—All necessary lubricators for supplying the slide valves, &c., with oil or tallow; water cooling pipes for the engines and shafting; ladders and flooring plates in the engine room, with fenders and guard rails; also spanner racks for the engine room, and racks for the stowage of fire irons in the stoke-hole.

Such parts of the engines as are usually painted to receive three coats of paint.

Drawings.—A drawing or tracing on cloth, to be supplied with the vessel, of the general arrangement of pipes and cocks throughout the whole ship, with the name and where it leads to, of each pipe, cock, and valve, lettered thereon. The engines and boilers to be securely fixed on board, the latter by chocks at the lower part; and when finished delivered over with the vessel to the owner.

All expenses, dock dues, &c., to be borne by the builders till that time.

The machinery to be tried with the vessel on the measured mile previously to being accepted, the contractors finding the coal and all requisites for such trial.

Completion.—This specification is intended to include the whole of the fittings in connection with the engine department, usual in vessels of first class build, as that with the exception of stores, the ship shall in all respects as regards the engine department be complete and ready for sea. It is therefore, expressly to be understood that all minor fittings, which may not be mentioned in this specification, but which is considered requisite for the proper completion of the machinery, are to be provided without extra charge.

Inspection.—The contract is to be executed in every respect to the satisfaction of the engineer inspector appointed to inspect the machinery, while it is being constructed, on the premises of the contractors, and being erected on board the ship.

Machinery to be Guaranteed for Twelve Months.—The contractors will be held responsible for the efficiency of the machinery, for a period of twelve months after the contract has been accepted, and any parts which may during that period be found defective or showing symptoms of weakness, owing to faulty design, materials, or workmanship, must be removed and others be substituted for them by the contractors and at their expense.

List of Tools and Spare Gear.

Engineer's Tools.	No. of.
Brushes for boiler tubes	6.
„ „ condenser tubes	6.
Drifts, short and long	1 each.
Fire irons (assorted)	6.
Mandrils	1 each.

ENGINEER'S TOOLS.—*Continued.*	No. of.
Scrapers, circular and forked	3 each.
Spanners	36 sizes.
Taps and dies, from ¼ to 1¼ in.	1 set.

SPARE GEAR.

Air pump rod	1.
„ „ connecting rod	1.
Furnace bars	1 set.
„ „ bearers	1 „
Boiler plates	3 cwt.
Bolts and nuts (assorted), part of these to be turned bolts ...	120.
Cylinder cover	1.
Crosshead, with guide blocks...	1.
Eccentric brasses ... ... of each size	1.
Fan and spindle for centrifugal pump	1.
Ferrules for boiler tubes	1 set.
Steam gauge for boiler	1.
Glasses for each gauge	1.
Lignum vitæ strips	1 set.
Piston rod	1.
Propeller blade (if bolted), right and left, with bolts and fittings complete	1 each.
Connecting rod	1.
Feed pump rod	1.
Valve spindle	1.
Slide valve	1.
Packing screws for piston	1 set.
Springs for piston	1 „
„ „ safety valves	½ „
„ „ other valves ... ... each	½ „
Thrust collars	1 „
Boiler tubes, including stay tubes	20.
Glass tubes for water gauges, for boiler	2 sets.
Condenser tubes ... ... 1-20th of the whole number.	
„ packing ... ... for the above number of tubes.	
Condenser tube screw glands ... for 1-80th of the whole set of tubes.	
Indiarubber valves ... ... for each engine	2 sets.
Iron washers (assorted)	1 gross.
White metal	14 lbs.

And any other article deemed necessary to the particular kind of engine tendered for.

Note.—The foregoing specification is a representative one, for a vessel of the best possible build, and which, for ordinary cases, might be modified to suit circumstances and requirements.

THE STEERING OF SCREW STEAM YACHTS.

Coeval with the introduction of the "screw," it was known that the action of a propeller on a ship whose helm was amidships would tend to turn her; that is, a right-handed screw would turn the ship's head to starboard, and a left-handed one to port. It was also known by experiments made with the "*Great Britain*" in 1845 that a propeller, if suddenly reversed, would tend to turn a ship against her helm until her way was stopped. In spite of this knowledge, much attention does not appear to have been given to the subject until three or four years ago, when several accidents were clearly traceable to the fact that the vessels turned the opposite way to that expected under port or starboard helm, whilst their screws were being reversed to deaden their way. Professor Osborne Reynolds gave the subject much attention, and at last, in 1877, got a committee appointed, consisting of himself, Mr. James R. Napier, Sir William Thomson, and Mr. W. Froude, to inquire into the matter. The committee made experiments with the Duke of Argyll's steam yacht "*Columba*," the Earl of Glasgow's steam yacht "*Valetta*," and several large steamers in the merchant navy.

The result of the experiments bore out all that was previously known or suspected of the action of the screw on the steering. With the steamer going nine or ten knots ahead, the engines were suddenly stopped and reversed; simultaneously with the reversal of the engines, the helm was put hard a-port, the vessel, of course, still forging ahead. According to what is usual, with the helm hard aport the ship's head should have turned to starboard; but, instead of doing this, her head went off to port twenty-eight degrees, or about two and a half compass points, before the vessels way was stopped. Next, the ship was turned full speed ahead again, and when she had full way on, the engines were stopped and reversed as before, but the helm was put hard a-starboard. Between the moment of reversing the engines and that of the ship's way being stopped, the ship turned forty degrees to starboard, or nearly four points, or nearly one-eighth of a circle. The experiment was tried over and over again, and the inevitable result was that, during the interval of reversing the engines and the stoppage of the ship, the rudder acted just the contrary to the way expected.

A fact not generally known was brought to light, that the effect of the screw is largely governed by its immersion, and that its influence is greatest on the steering when it is near the surface "churning" the water. When deeply immersed it has little or no effect of itself in turning a ship one way or the other, and never under the most favourable circumstances—that is, with the screw near the surface, and a low speed —could the ship be got round in a circle less than double the radius of the one she would describe under the influence of her rudder with the engines turning ahead.

Also it was clearly proved that an experiment is required for every

individual vessel, and for varying speeds; thus, one steam yacht, with helm hard one way or the other, may keep a straight or nearly straight course whilst her engines are reversed and before she stops, and another may turn to the opposite way that her rudder has been put. It is thus necessary that a simple experiment should be made for every screw steam yacht, so that her master might be acquainted with her behaviour as to steering whilst her engines are being reversed. It can, perhaps, be said that a vessel turning through an arc of twenty or forty degrees cannot be of much consequence when her way is being stopped; and it might not be if it was clearly understood which way she was going to turn. It might, however, be of the utmost consequence, if the vessel whilst losing her way turned thirty degrees to port, instead of thirty degrees to starboard. This would practically be a difference of sixty degrees, or two-thirds of a quadrant, and would be quite sufficient to bring about such disasters as those of the "*Dakota*" and "*Ville du Havre.*"

One other result of the experiments was to make patent what was not very generally known, that the reversal of the engines of a screw steamer has but trifling effect on stopping her way; and that the distance required to bring a screw steamer to rest mainly depends upon her size, weight, form, and speed. The distance may roughly be put down as five or six times her own length.

These peculiarities of screw steamers should be well known and be well considered by all in charge of screw steamers, as it is quite plain that "full speed astern" may often bring about a collision, when steaming ahead and using the rudder might avoid it. This may be especially the case if a steamer is approaching another, or approaching a shore, in an oblique direction. Say that the ship or shore bears on her port bow six or seven lengths off, and by continuing she would strike the ship, or in the case of the shore go aground; if she ported her helm and reversed, she would be carried probably stem on the very object she hoped to avoid; whereas by porting her helm and steaming ahead she might have cleared it, or by only stopping the engines, and not reversing them, she might have gone clear.

A screw steamer will generally turn in a circle whose radius is about four times her own length, and stop in a distance equal to about six times her own length; thus far, if the object to be avoided were six lengths off, it could be better cleared by turning under full speed than by reversing or stopping. This, however, supposes that the steamer can be given her full rudder power (about thirty-five degrees) at once; whereas the fact is that it takes a very considerable time to get a rudder hard over when a steamer is at full speed, and very seldom is there power enough at the helm—perhaps only one man—at the moment to do it. Of course, by stopping the engines the power gained by the helmsman over the rudder would be increased; and generally it would appear to be the wisest plan, when a screw ship gets into such a position that it is almost certain she will strike some object ahead, for her to stop her engines and put the helm over just as if the engines were still turning ahead. Of course, the

engines could be reversed, and the helm put the other way, to assist the effect of the backward motion of the screw on the turning; but, unless the person in charge is thoroughly acquainted with the behaviour of the ship under all conditions, simply stopping the engines and making as much use of the rudder as possible would appear to be the wisest course.

As before said, very few steam yachts behave exactly the same under the influence of the rudder and stern way, or under the influence of the screw alone without the rudder; and it will be found incumbent in most cases to make an experiment with every steamer in order to discover her peculiarities. In the first place, it should be ascertained how far she will go before losing way when the engines are stopped from full speed ahead, and from half speed ahead; also the distance she will traverse before losing way whilst assisted by the engines being reversed. Next it should be ascertained how many compass points the vessel will turn before losing way; and how many points she will turn and in what direction, before losing way, whilst the engines are being reversed. Also, the steering should be tested whilst the steamer has stern way on.—*The Field.*

THE ACTION OF THE STEAM IN THE CYLINDERS OF A PAIR OF COMPOUND ENGINES. (Plate 1.)

This plate illustrates a pair of cylinders of the inverted direct acting type of engine, with an intermediate receiver. The cylinders are not steam jacketed, and have a capacity in proportion to each other of 1 to 2·84; while the intermediate receiver, which surrounds the high-pressure cylinder, has a capacity equal to that of the high-pressure cylinder. The valve chest of the high-pressure cylinder is situated at the forward end of the engines, and that for the low-pressure cylinder between the cylinders; the valves of both cylinders are double ported. Upon reference to the sectional elevation and plan the construction of the steam and exhaust passages may be readily followed; as also the direction of the steam in its passage through the engines, as indicated by the barbed arrows. Those with one barb represent the steam from the boiler in its passage through the steam ports of the high-pressure valve, to the underside of the high-pressure piston; those with two barbs represent the steam after doing its part of the work in the high-pressure cylinder, passing from the top of the piston, through the exhaust port into the receiver, and from thence into the admission port of the low-pressure cylinder, to the top side of the low-pressure piston; those arrows with three barbs indicate the exhausting steam from the under side of the piston, through the exhaust, and into the condenser. The valves in their present position are both moving upwards—the high-pressure piston is on

the up stroke, and the low-pressure piston on the down stroke. The low-pressure slide valve is just about to close the communication between the two cylinders; the low-pressure piston will then perform the remainder of its stroke due to expansion, the under side being open to the condenser. The low-pressure slide will continue to close both ports, until the high-pressure piston has reached half its stroke. During the whole of the time the ports of the low-pressure cylinder are closed, compression takes place above the high-pressure piston and in the receiver. When the low-pressure piston gets to the end of its stroke, the valve opens again the communication between the two cylinders. The first upward impulse is given by the steam compressed in the receiver, and above the high-pressure piston. The top of the low-pressure cylinder will then be open to the condenser; by this time both pistons would be on the up stroke. When the high-pressure piston is at two-thirds of its stroke, the high-pressure slide, moving down, cuts off the initial steam supplied to the small cylinder from the boiler, the remaining one-third being performed by expansion. The high-pressure valve will close the top port to the low-pressure cylinder, and open the communication at the bottom between the two cylinders, the bottom of the small cylinder being open to the bottom of the large cylinder—the fresh influx of steam increasing the pressure on the low-pressure piston. The high-pressure piston will then be round the top centre, and on its down-stroke receives a fresh supply of steam from the boiler. The low-pressure valve moving down, will cut off the exhaust from the high-pressure cylinder, and the low-pressure piston will perform the remaining fourth of its stroke by expansion. During this time, compression again takes place and continues until the low-pressure piston has completed its stroke; so when it is round the centre, it has steam at an increased pressure as before, the bottom port being again open to the condenser. Both pistons will continue their down stroke, cut off as before, and will be ready for a fresh stroke in their turns. It will be seen that while the exhaust steam in the small cylinder has free access to the large cylinder, with the assistance of the condenser there will be an equality of pressure in the two cylinders, which retards the motion to the high-pressure piston, while it gives motion to the low-pressure piston. This retarding pressure on the high-pressure piston is not a loss, since the steam causing it, is not losing its pressure so rapidly, as it would have done had the high-pressure piston been stationary—the real effect of the steam being, that, due to the number of times the contents of the large cylinder are greater than the contents of that portion of the small cylinder which is supplied with steam from the boiler. Practically there is little loss from this compression, and the smaller the passages between the cylinders the less steam there will be dispersed, as the compressed steam maintains the pressure and heat; which is advantageous to its action and expansion in the large cylinder.

COMPOUND ENGINES.

ADMIRALTY DIRECTIONS TO ENGINEERS.

The greatest care and attention will have to be paid to these engines by the engineer officers in charge of them. They should make themselves thoroughly acquainted with the principles of their design, and discover the methods of working them with the greatest degree of economy.

If expansion valves are fitted to the low-pressure cylinders, it must be borne in mind that the use of these valves will not so much alter the total work done by the engines, as it will the ratio of the work in the high and low-pressure cylinders. It is believed however that in the generality of cases, the judicious use of these valves, especially when working at low rates of speed, will increase the total work done for a given expenditure of coal, and will thus conduce to economy; but their principal use will be to regulate the work done in the different cylinders.

If these valves be not used, it will probably be found that when working at low rates of speed nearly all the work will be done in the high-pressure cylinders; and that the work done in the low-pressure cylinders will be barely sufficient to overcome the weight and friction of their pistons, &c., and may even be so bad in some engines, that the low-pressure cylinders may prove a drag on the high-pressure cylinders.

The engineer officers in charge of engines so fitted, must use their best endeavours to determine the proper rates of expansion, in each cylinder, for the different rates of speed. In order to determine this, the grade of expansion in the low-pressure cylinder is to be changed occasionally, when proceeding at any given rate of speed; and, at each grade of expansion, diagrams are to be taken from each of the cylinders, and the power developed in each compared.

It will be found that the higher the rate of expansion in the low-pressure cylinders, the greater will be the pressure in the reservoir, and consequently the back-pressure in the high-pressure cylinders, so that by increasing the rate of expansion in the low-pressure cylinders, the power developed will be increased in them, and decreased in the high-pressure cylinders.

In the case of those Compound Engines, whose low-pressure cylinders are not fitted with expansion valves, the Engineer Officers may in many cases, follow the above directions to some extent, by working expansively in the low-pressure cylinders by means of the link-motion, and probably considerable gain will be effected by this method.

The Engineer Officers must be careful in making these experiments, not to work at such a high rate of expansion in the low-pressure cylinders, as to cause the pressure in the reservoir to rise too high. If when working at or near full power, the grade of expansion in the low-pressure cylinders be too high, the power developed in it will be unduly increased, as also may be the strains on the crank-shaft.

When the proper grades of expansion in the low-pressure cylinders are once determined for the different speeds, they are to be noted, so that if it

be necessary at any time to alter the power of the engines, there shall be no difficulty in setting the expansion valves on the low-pressure cylinders at the proper grades for the altered power.

BOILERS.

A case having recently occurred when the man and mud-hole doors of a boiler were opened, deleterious gas was found to arise therefrom for some time. The Admiralty direct that the following precautions be taken to prevent accidents happening from such a cause:—1. Whenever boilers are opened, sufficient time is to be allowed for any foul gas to escape. 2. Before anyone is allowed to enter them, the purity of the air is to be ascertained by the candle test,—that is, no man is to enter until a lighted candle has been held in it for at least five minutes; and that men are to be warned that they should leave immediately the light begins to burn dimly. A candle is to be used as a safer test than a lamp, as it may be thought that a lamp burned dimly for want of trimming.

MISCELLANEOUS NOTES.

Management of the Fires in Steam Vessels.—"The management of the fires on board a steam vessel affects the question of economy in the consumption of coal to so great an extent, that the importance of skilful firemen cannot be too much insisted upon. It is a great mistake to suppose, as too many captains and owners of steam vessels do, that any able-bodied man who can throw coals on a fire is fit for a stoker; and under this false impression sailors are frequently engaged, instead of regular firemen, 'to stoke when required.' The only cases in which this should be allowed are, perhaps, in auxiliary screw vessels, and in such vessels as may be expected to make a considerable portion of their voyage under canvas; but, even in such cases, there should always be one well-trained fireman for each watch, to have the charge of the other stokers. This man should be kept constantly at his post, and must not be liable to be called away while the vessel is under steam, except in cases of emergency; and he should receive a higher rate of pay than the other stokers, if it were only for the purpose of giving him the necessary authority over them."

Effects of Mismanagement.—"Many instances of steamers are to be found at the present day in which the same quantity of coal is regularly burnt per hour, whether the engines are going fast or slow, whether forty cylinders full of steam are used per minute, or only thirty. In such a case one-quarter of the fuel is thrown away, through ignorance of the despised art of stoking; for the firemen may have either allowed the surplus steam generated to blow-off at the waste steam pipe, or they may have thrown

open the fire-doors; by which means the steam is only prevented from being generated by the rush of cold air which takes place through the flues, while the same quantity of coal is burnt as before.

The Explosive Effect of Steam.—A cubic foot of water, at the temperature of steam at 60 lbs. pressure, equals the explosive effect of 1 lb. of gunpowder; so that with a boiler containing 100 cubic feet of water in the event of an explosion there would be the same effect or havoc, as would result from the explosion of 100 lbs. of gunpowder. This will show the necessity of being careful that the steam pressure in a boiler never exceeds the strength of the plates to resist it, and that the plates be closely examined, to find if they, at any part, have worn thinner than is consistent with safety.

Rule for Boiler Pressures :—

To determine the safe working-pressure for any Cylindrical Boiler, and the thickness of plate at the thinnest part of Boiler, due to corrosion or wear,

$$\frac{\text{Twice the least thickness} \times \text{Factor of Safety}}{\text{Diameter of Boiler in inches.}} = \text{Safe pressure to carry.}$$

Taking the breaking-strain of wrought-iron at 22 tons, or 49,280 lbs., and one-tenth of this for the factor of safety, would be 4,928 lbs.

By adopting one-tenth, we cover all the objections the Board of Trade are likely to issue against inefficient rivetting.

Slaking Bearings.—Whenever it is absolutely necessary to slack a bearing, so as to take away its support from the shaft, the engines ought at the same time to be slowed down, so that there should not be such a great load on the crank pins.

COALS.—Cubic feet of Coal, multiplied by ·0345, gives tons.
" " ·023, " stowage.

OIL.—One Cubic foot = 6·23 gallons.
" = ·58 lbs.
Lbs. divided by 9 = gallons approximate.

TALLOW.—One Cubic foot = 59 lbs.

COTTON WASTE.—One Cubic foot = 11 lbs.

COAL ON TRIAL TRIPS.—The estimated consumpt of Coal on long voyages is one-half greater than the consumpt on Trial Trips.

TO DETERMINE THE SAFE THICKNESS OF COPPER PIPES.

$$\frac{\text{Dia.} \times \text{pressure}}{4000} = \text{Thickness.}$$

KNOTS PER HOUR.

$$\frac{\text{Revolutions per minute} \times \text{pitch in feet}}{100} = \text{Knots per hour.}$$

Quick Drying Boiled Oil.—To every gallon of linseed oil add 1 lb. of litharge and half a pound of red lead. Put the vessel containing these on a slow fire, and, allowing the heat to increase, steadily boil for three hours. After removing from the fire let it remain still for twenty-four hours, then remove the scum from the top and use when required.

Putty for Skylights, &c.—Mix 60 lbs. of well dried whiting in 1 gallon of linseed oil. Leave it for a week. Then work well up together again before using; the addition of a little alum, finely powdered, will make the putty dry very hard.

Dryers in Paint.—The proper proportion of patent dryers to use in paint is half an ounce to every pound of colour.

MEASURED MILE SPEED TABLE.

SECONDS.

Min.	0	3	6	9	12	15	18	21	24	27
	NAUTICAL MILES PER HOUR.									
3	20·000	19·672	19·355	19·047	18·750	18·461	18·181	17·910	17·647	17·391
4	15·000	14·815	14·634	14·457	14·285	14·118	13·953	13·793	13·636	13·483
5	12·000	11·880	11·764	11·650	11·538	11·428	11·321	11·215	11·111	11·009
6	10·000	9·917	9·830	9·756	9·677	9·600	9·524	9·448	9·375	9·302
7	8·571	8·510	8·450	8·391	8·333	8·275	8·219	8·163	8·108	8·059

SECONDS.

Min.	30	33	36	39	42	45	48	51	54	57
	NAUTICAL MILES PER HOUR.									
3	17·143	16·901	16·667	16·438	16·216	16·000	15·789	15.584	15·384	15·190
4	13·333	13·186	13·043	12·903	12·766	12·631	12·500	12·371	12·245	12·121
5	10·909	10·810	10·714	10·619	10·526	10·434	10·345	10·256	10·169	10·084
6	9·230	9.160	9·090	9·022	8·955	8.889	8·823	8·759	8·695	8·633
7	8·000	7·947	7·895	7·843	7·792	7·741	7·692	7·643	7·595	7·547

Table Showing the Distance in Miles and Furlongs between Landmarks from LONDON BRIDGE TO OXFORD.

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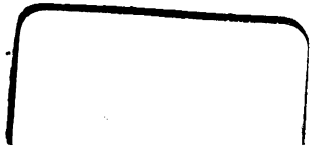
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